AFRL-RH-BR-TR-2009-0034

24/7 OPERATIONAL EFFECTIVENESS TOOLSET: PPREDICTIONS OF FAST™ AND F-PAS

Douglas R. Eddy
Juan Mendez

NTI, Incorporated
1 ½ South Central Ave
Fairborn, OH 45324

November 2008

Interim Report for May 2006 – May 2007

Approved for public release;
distribution unlimited, Public Affairs
Case File No. 09-306, 6 July 2009.

Air Force Research Laboratory
711 Human Performance Wing
Human Effectiveness Directorate
Biosciences and Protection Division
Biobehavioral Performance Branch
Brooks City-Base, TX 78235

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_____//SIGNED//_____	____//SIGNED//_____
SHARON K. GARCIA	MARK M. HOFFMAN
Work Unit Monitor	Deputy Division Chief
Biobehavioral Performance Branch	Biosciences and Protection Division
	Human Effectiveness Directorate
	711 Human Performance Wing
	Air Force Research Lab

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE *(DD-MM-YYYY)*	**2. REPORT TYPE**	**3. DATES COVERED** *(From - To)*
01-11-08	Interim Technical Report	5-1-2006 to 5-1-2007

4. TITLE AND SUBTITLE
24/7 Operational Effectiveness Toolset: Predictions of FAST™ and F-PAS Compared

5a. CONTRACT NUMBER
FA8650-06-C-6606

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Douglas R. Eddy and Juan Mendez

5d. PROJECT NUMBER
5020

5e. TASK NUMBER
P9

5f. WORK UNIT NUMBER
09

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

NTI, Inc.
1 ½ S. Central Ave.
Fairborn, OH 65324

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Materiel Command
2485 Gillingham Dr
Air Force Research Laboratory
711 Human Performance Wing
Human Effectiveness Directorate
Biosciences and Protection Division
Brooks City-Base, TX 78235

10. SPONSOR/MONITOR'S ACRONYM(S)
711 HPW/RHP

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-RH-BR-TR-2009-0034

12. DISTRIBUTION / AVAILABILITY STATEMENT
Distribution A. Approved for public release; distribution unlimited, Public Affairs Case file no. 09-306, 6 July 2009

13. SUPPLEMENTARY NOTES

14. ABSTRACT
The purpose of the work reported here was to validate the core software components of a new web-based version of the Fatigue Avoidance Scheduling Tool (FAST™). Four different schedules were used to compare the performance effectiveness projections of the two computer applications. The methods used to compare the data were taken from Chaiken (2005). The preliminary comparisons revealed discrepancies between the applications that were unacceptable. After modifications to the Core Software, an additional validation was conducted. The second comparison resulted in excellent agreement between the web-based Core Software and FAST™. The two tools allow users to predict cognitive performance effectiveness based on the timing and amount of sleep an individual or team receives prior to and during a mission. They provide the military planner the ability to optimize performance under conditions of limited sleep, thus minimizing the need for pharmacological aids while indicating work periods where additional fatigue countermeasures may be necessary.

With the validation of the Core Software, the new web-based tool was enhanced with new user interfaces for mishap investigation, shift work scheduling, mission scheduling, AMC pilot rescheduling after an interrupted mission, and AF flight surgeon fatigue countermeasures applications reported elsewhere. The web-based tool is called the Fatigue-Performance Assessment System (F-PAS).

15. SUBJECT TERMS
Fatigue management, Cognitive performance, Sleep, Circadian Rhythm, Verification, Validation and Accreditation

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON**
U					Dr. Sharon Garcia
a. REPORT	**b.ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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PREFACE

The contract technical monitor for this work was Dr. Scott Chaiken and previously Dr. James C. Miller, AFRL/HEPF. The program managers were Lt Andrea Pinchak and previously Lt Andrew Workman both of the Biosciences and Protection Division, AFRL 711 HPW/RHPF. The work was performed under work unit number 5020P909. This report satisfies the contract requirements for Report 3.2.2, Task 1.2 in the contract statement of work.

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TABLE OF CONTENTS

PREFACE ii
SUMMARY vii
INTRODUCTION 1
PURPOSE OF THE WORK 1
METHODS 2
PROCEDURES 2
RESULTS 3
FIRST VERSION OF CORE SOFTWARE (CORE1) 3
Test Schedule 1 3
Test Schedule 2 4
Test Schedule 3 7
Test Schedule 4 11
SECOND VERSION OF CORE SOFTWARE (CORE2) 15
Test Schedule 1 16
Test Schedule 2 17
Test Schedule 3 19
Test Schedule 4 22
CORE SOFTWARE AFTER ADDING THE PHARMACEUTICAL FATIGUE COUNTERMEASURES ALGORITHM (CORE3) 25
Test Schedule 1 25
Test Schedule 2 27
Test Schedule 3 28
Test Schedule 4 31
DISCUSSION 34
CONCLUSIONS 35
REFERENCES 36

FIGURES

Figure 1. FAST™ and CORE1 performance effectiveness (PE) projections for Schedule 1 for three of the first-minute dependent measures are shown in this graph. 4
Figure 2. Plot of FAST™ and CORE1 PE projections from Schedule 2 for the first minute of sleep each day. 6
Figure 3. Plot of FAST™ and CORE1 PE projections from Schedule 2 for the first minute awake each day. 6
Figure 4. Plot of FAST™ and CORE1 PE projections from Schedule 2 for the first minute of work each day. 7
Figure 5. Plot of FAST™ and CORE1 PE projections from Schedule 3 for the first minute of sleep each day. 10
Figure 6. Plot of FAST™ and CORE1 performance effectiveness projections from Schedule 3 for the first minute awake each day. 10
Figure 7. Plot of FAST™ and CORE1 PE projections from Schedule 3 for the first minute of work each day. 11

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Figure 8. Plot of FAST™ and CORE1 PE projections from Schedule 4 for the first minute of sleep each day. 14
Figure 9. Plot of FAST™ and CORE1 PE projections from Schedule 4 for the first minute awake each day. 14
Figure 10. Plot of FAST™ and CORE1 PE projections from Schedule 4 for the first minute of work each day. 15

TABLES

Table 1. Sleep and Work Times for Schedule 1. 3
Table 2. Table of Travel Times and Locations for Schedule 2. 4
Table 3. Sleep and Work Times for Schedule 2. 5
Table 4. Sleep Times for Schedule 3. 8
Table 5. Work Times for Schedule 3. 9
Table 6. Sleep Times for Schedule 4. 12
Table 7. Work Times for Schedule 4. 13
Table 8. Comparison of FAST™ and CORE2 PE for last and first minute awake from Schedule 1. 17
Table 9. Comparison of FAST™ and CORE2 PE for last minute of sleep and first minute of work from Schedule 1. 17
Table 10. Comparison of FAST™ and CORE2 PE for last and first minute awake from Schedule 2. 18
Table 11. Comparison of FAST™ and CORE2 PE for last minute of sleep and first minute of work from Schedule 2. 18
Table 12. Comparison of FAST™ and CORE2 PE for last and first minute awake from Schedule 3. 20
Table 13. Comparison of FAST™ and CORE2 PE for last minute of sleep and first minute of work from Schedule 3. 21
Table 14. Comparison of FAST™ and CORE2 PE for last and first minute awake from Schedule 4. 22
Table 15. Comparison of FAST™ and CORE2 PE for last minute of sleep and first minute of work from Schedule 4. 24
Table 16. Comparison of FAST™ and CORE3 PE for last and first minute awake from Schedule 1. 26
Table 17. Comparison of FAST™ and CORE3 PE for last minute of sleep and first minute of work from Schedule 1. 26
Table 18. Comparison of FAST™ and CORE3 PE for last and first minute awake from Schedule 2. 27
Table 19. Comparison of FAST™ and CORE3 PE for last minute of sleep and first minute of work from Schedule 2. 28
Table 20. Comparison of FAST™ and CORE3 PE for last and first minute awake from Schedule 3. 29
Table 21. Comparison of FAST™ and CORE3 PE for last minute of sleep and first minute of work from Schedule 3. 30

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Table 22. Comparison of FAST™ and CORE3 PE for last and first minute awake from Schedule 4. 31
Table 23. Comparison of FAST™ and CORE3 PE for last minute of sleep and first minute of work from Schedule 4. 33

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SUMMARY

The Fatigue Avoidance Scheduling Tool (FAST™) allows users to predict cognitive performance and effectiveness based on the timing and amount of sleep an individual or team receives prior to and during a mission. It provides the military planner a tool to optimize performance under conditions of limited sleep, thus minimizing the need for pharmacological aids while indicating work periods where additional fatigue countermeasures may be necessary. The Air Force desired a browser accessible version of the software with specialized interfaces and funded the work through a Phase 3, SBIR contract. This report describes the results of testing the Core Software for the browser-accessible version against FAST™. Once the Core Software was successfully validated, the development team would be assured that the core software was functioning properly and could then proceed to add the new features and embellishments.

The verification was one small part of the overall contract. The testing was fashioned after the methods used by Chaiken (2005), who verified that the FAST™ software was an accurate representation of the SAFTE model. The testing in this report compared performance effectiveness predictions for four different schedules. The results from the second version of the Core Software provided output that differed from FAST™ by less than 1% at worst. The insignificant error was unsystematic and appeared to be due to rounding differences between the two different programming languages.

With the validation of the Core Software, the new web-based tool was enhanced with new user interfaces for mishap investigation, shift work scheduling, mission scheduling, pilot rescheduling after an interrupted mission, and AF flight surgeon fatigue countermeasures applications. The interfaces were designed using task-centered analyses.

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INTRODUCTION

The Fatigue Avoidance Scheduling Tool (FAST™), a computer application, allows users to predict cognitive performance effectiveness based on the timing and amount of sleep an individual or team receives prior to and during a mission. It provides the military planner a tool to optimize performance under conditions of limited sleep, thus minimizing the need for pharmacological aids while indicating work periods where additional fatigue countermeasures may be necessary. The FAST™ application is used by Air Force (AF) mission schedulers to plan long duration bombing runs, by AF and railroad mishap investigators to assess possible fatigue effects, and by AF, Navy, and Army physiologists and physicians to understand and counter fatigue effects in training and mission planning.

The FAST™ application grew out of a desire by a small group of scientists at Brooks City Base, in San Antonio, Texas, to put the best fatigue and performance model into a tool that could be used by military planners to minimize the effects of fatigue on aircrews and other military units (Eddy & Hursh, 2001, 2006a, 2006b). The tool had to be reasonably accurate using data available to a mission planner. After it was determined that the Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model was best (Hursh, Redmond, Johnson, et al., 2004), Dr. Steven Hursh, the inventor, was contacted to be a collaborator on the project. The SAFTE model has since been validated in both aviation (Eddy & Hursh, 2006b) and railroad (Hursh, Raslear, Kaye, & Fanzone, 2006) work environments. Although the project was a success, the interface designed by scientists for scientists was not easily used by AF planners and investigators. In addition, the AF was moving toward browser accessible software products rather than software running off a user's computer. Therefore, the AF decided to fund a spin-off product that would meet the needs of several different AF user groups, be Web-based, include pharmaceutical fatigue countermeasures, and be browser accessible. This new software is called the Fatigue-Performance Assessment System (F-PAS).

This report describes the results of testing the first three browser accessible versions of the core software (dated March 17, 2006, November 17, 2006, and December 17, 2007) against FAST™, Version 1.5.26U. The new algorithms, based on Wesensten, Killgore, & Balkin (2005), were added to the new Web-based software, but the countermeasures were not enabled for these verification tests. The two programs had to be functionally identical to make the comparisons. Only in that way, would it be possible to assess the proper functioning of the new core software prior to adding embellishments.

PURPOSE OF THE WORK

The purpose of this effort was to test the output of the Web-based Core Software against FAST™ output for the same set of schedules. The validation of the new software was one small part of the overall contract to convert the software to the new medium and add special interfaces to make it easy for AF personnel with different usage requirements to use the tool. It was important to validate the Core Software before embellishing it with new algorithms and features to guarantee that future output differences were resulting

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directly from the modifications, not from a variation in the Core Software. This unit testing could also be used by AF Computer Security to document the validity of the underlying model to gain a Certificate of Networthiness, which would allow AF users access to it on the World Wide Web. At a future time the pharmaceutical fatigue countermeasures will be activated with appropriate new

METHODS

Our validation effort was limited to the most important output of the programs, namely performance effectiveness. A complete validation would also involve lapses, light-dark conditions, and the fatigue indicators displayed on the tools dashboard. However, since these other output products are derived from performance effectiveness their validation follows automatically.

PROCEDURES

To make the comparison of the browser-based Core Software with FAST™ as easy as possible, our programmer created an interface to let the Core Software read FAST™ schedule files (.fas). The browser-based Core Software then returned a minute-by-minute performance effectiveness vector that could be compared with the same from FAST™. The actual comparison involved selecting time points relevant to the various schedules. The testing was fashioned after the methods used by Chaiken (2005), who verified that the FAST™ software was an accurate representation of the SAFTE model as defined in Hursh, Redmond, Johnson, et al. (2004) and in its patent description[1]. The schedule points used are listed below:

- First minute of the day
- Last minute of sleep before awake
- First minute of awake
- First minute of work
- Last minute of work
- First minute of no-work awake
- Last minute of awake before sleep
- First minute of sleep
- Last minute of the day

There were four schedules, each with different characteristics. The schedules were the ones that are delivered with the FAST™ software. Each schedule represented increasing complexity allowing assessment of the basic software components and then progressing to the more complicated and subtle functions. Problems may not show up in the simpler schedules, but may be revealed when the model is stressed in the more complex ones.

[1] The following links to patent website: http://appft1.uspto.gov/netacgi/nph-Parser?Sect1=PTO1&Sect2=HITOFF&d=PG01&p=1&u=%2Fnetahtml%2FPTO%2Fsrchnum.html&r=1&f=G&1=1&s1='20030018242'.PGNR.&OS=DN/20030018242&RS=DN/20030018242

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As each new version of the Core Software became available for testing from the programmers, it was exercised with the four scenarios. The results section contains three sections, corresponding to each of the three versions of the Core Software tested. Each section contains the test schedules with a short description followed by the sleep and work periods in tables. A graph follows the schedule tables showing a plot of performance effectiveness (PE) for the selected times for each day for FAST™ and the Core Software. Shown first are the scenario comparisons for the first version of the Core Software (CORE1) with FAST™. Following review of the data for all four scenarios for the first version, is a comparison with the second corrected Core Software (CORE2). To save space, measures that repeat the same pattern of similarity or difference between the Core Software and FAST™ versions are not graphed. In the last section, the data for the third version (CORE3) is compared with FAST™. The CORE3 version includes the changes to the Core Software necessary to implement the pharmaceutical fatigue countermeasures algorithms. Since the test scenarios do not include countermeasure events (FAST™ does not have these algorithms), these new CORE3 software features were not activated in the comparison.

RESULTS

FIRST VERSION OF CORE SOFTWARE (CORE1)

Test Schedule 1

Characteristics:

- 10-day schedule
- Standard sleep from 2300-0700
- Standard work from 0900-1700
- No travel during schedule

Table 1. Sleep and Work Times for Schedule 1.

Start Sleep		End Sleep		Start Work		End Work	
Day	**Time**	**Day**	**Time**	**Day**	**Time**	**Day**	**Time**
1	22:59	2	6:58	1	8:59	1	16:58
2	22:59	3	6:58	2	8:59	2	16:58
3	22:59	4	6:58	3	8:59	3	16:58
4	22:59	5	6:58	4	8:59	4	16:58
5	22:59	6	6:58	5	8:59	5	16:58
6	22:59	7	6:58	6	8:59	6	16:58
7	22:59	8	6:58	7	8:59	7	16:58
8	22:59	9	6:58	8	8:59	8	16:58
9	22:59	10	6:58	9	8:59	9	16:58
				10	8:59	10	16:58

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Figure 1 shows the relationship between FAST™ output and the Core Software (CORE1) output for the specific time points. Clear discrepancies exist between FAST™ and the initial version, CORE1, for the first minute awake and the first minute asleep. For the first minute of work, both applications gave very similar projections. The other dependent measures for the other times had similar mixed results.

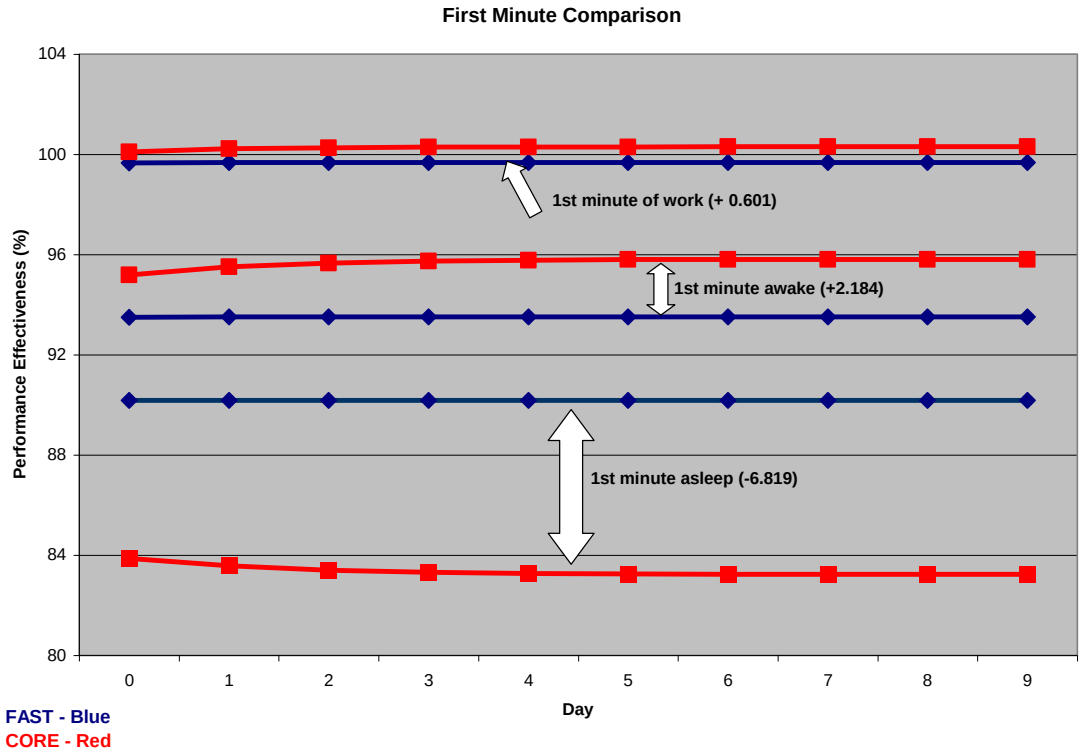

Figure 1. FAST™ and CORE1 performance effectiveness (PE) projections for Schedule 1 for three of the first-minute dependent measures are shown in this graph.

Test Schedule 2

Characteristics:

- 14-day schedule
- Travel from New York to Rome
- Six hour phase advance on the third day follows the location change shown in Table 2
- Sleep and work times are affected by the transmeridian travel as shown in Table 3

Table 2. Table of Travel Times and Locations for Schedule 2.

Day	Time	Lat	Lon	Description
3	8:00	40° 39' N	73° 47' W	Depart New York
3	16:00	41° 48' N	12° 36' E	Arrive Rome

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Table 3. Sleep and Work Times for Schedule 2.

Sleep Start		Sleep End		Work Start		Work End	
Day	**Time**	**Day**	**Time**	**Day**	**Time**	**Day**	**Time**
1	22:59	2	6:58				
2	22:59	3	6:58	2	9:00	2	16:59
3	16:59	4	0:58				
4	16:59	5	0:58	4	2:00	4	9:59
5	16:59	6	0:58	5	2:00	5	9:59
6	15:59	7	0:58	6	2:00	6	9:59
7	16:59	8	0:58	7	2:00	7	9:59
8	16:59	9	0:58	8	2:00	8	9:59
9	15:59	10	0:58	9	2:00	9	9:59
10	16:59	11	0:58	10	2:00	10	9:59
11	16:59	12	0:58	11	2:00	11	9:59
12	16:59	13	0:58	12	2:00	12	9:59
13	16:59	14	0:58	13	2:00	13	9:59
				14	2:00	14	9:59

Figure 2 shows a plot of PE for the first minute of sleep for each sleep period. FAST™ showed PE between 85 and 91% except for a 96% spike on Day 2. The CORE1 version showed poorer performance for the first four days and then deteriorated even more for the remaining days unlike FAST™. Figure 3 shows PE for the first minute awake. After the change of location on the third day, FAST™ PE declined to a low of 78.5% on Day 5, but slowly improved thereafter. The PE for the CORE1 version followed a similar trend to the fifth day, but continued to slowly degrade thereafter instead of showing improvement. Figure 4 shows a similar pattern for the first minute of work

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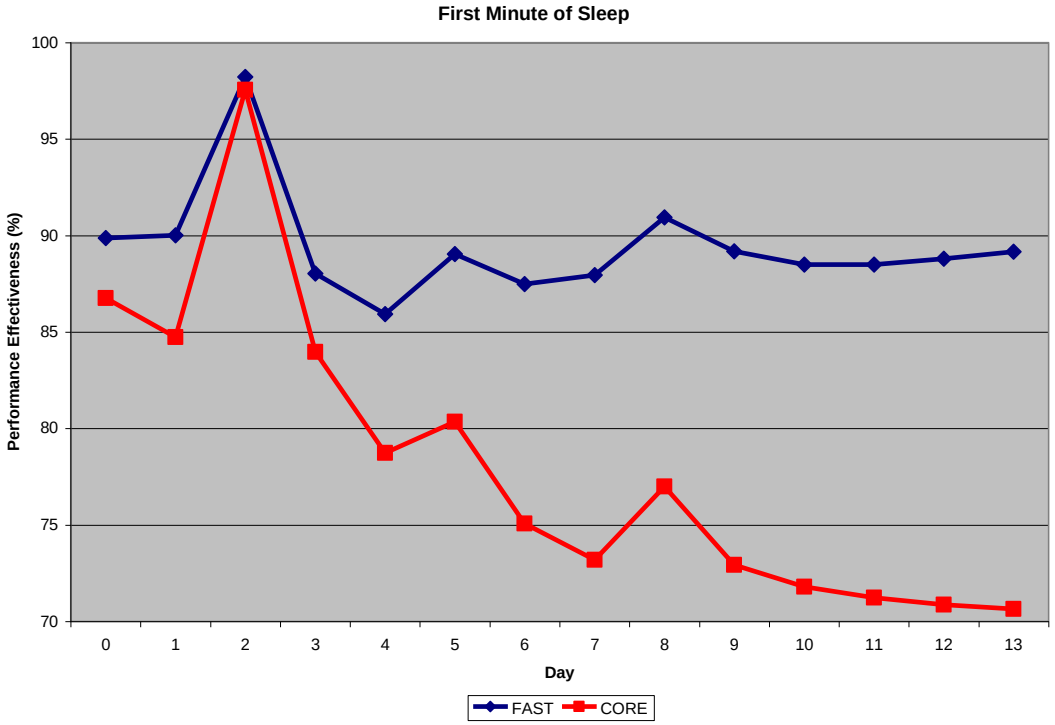

Figure 2. Plot of FAST™ and CORE1 PE projections from Schedule 2 for the first minute of sleep each day.

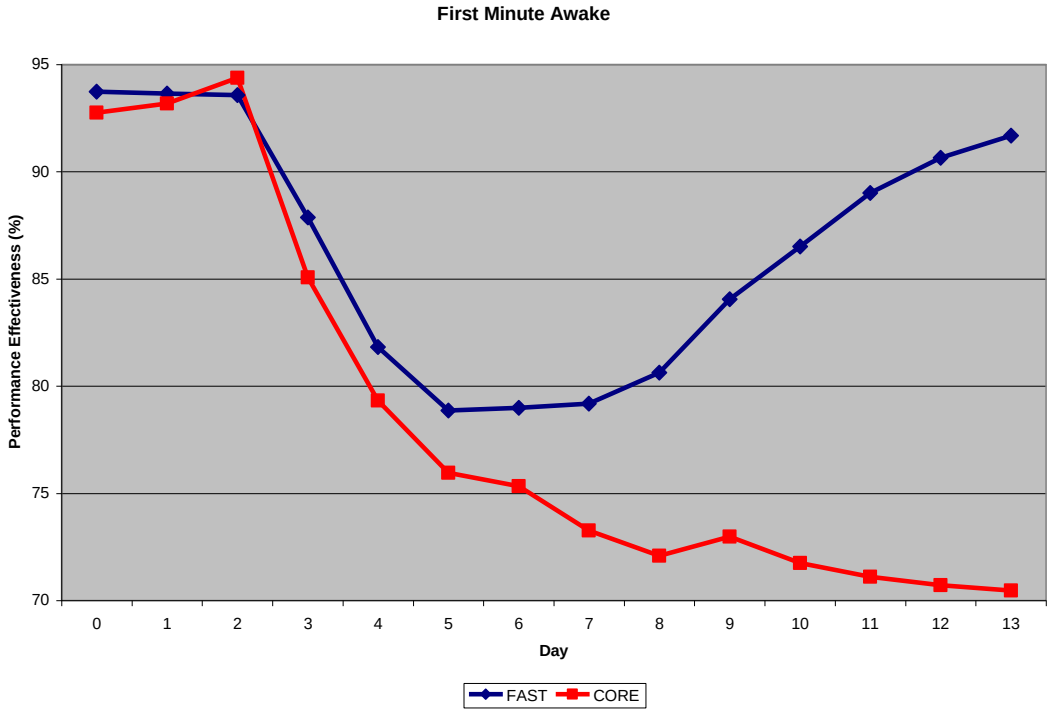

Figure 3. Plot of FAST™ and CORE1 PE projections from Schedule 2 for the first minute awake each day.

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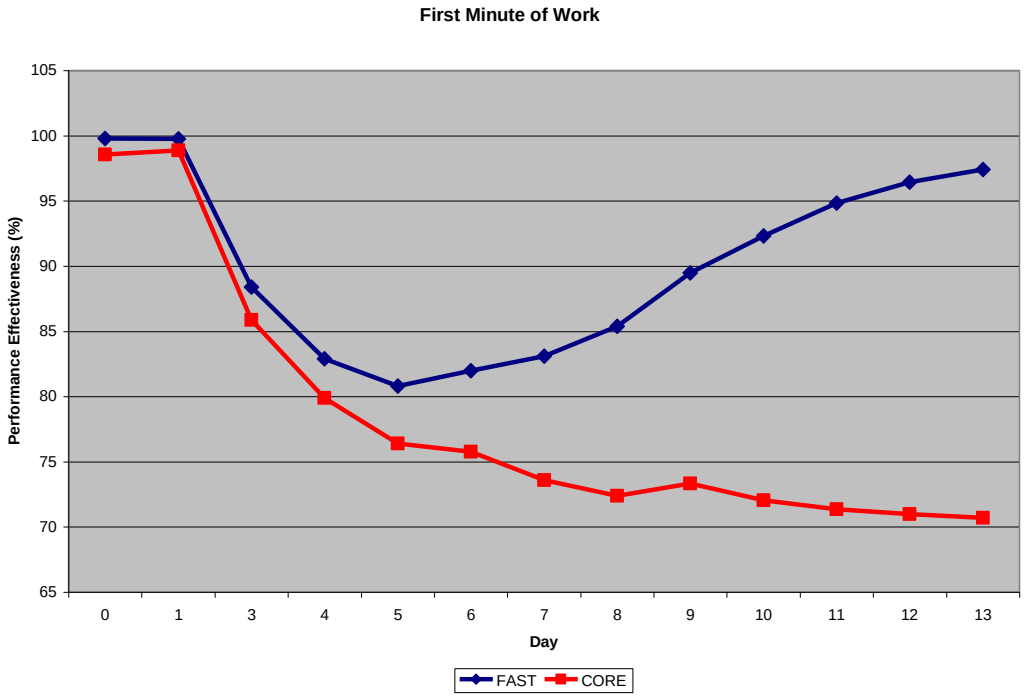

Figure 4. Plot of FAST™ and CORE1 PE projections from Schedule 2 for the first minute of work each day.

Test Schedule 3

Characteristics:

- 42-day, counterclockwise shift rotation schedule
- No work on weekends
- Two-day shift rotations start after working a day-time shift for a week
- Sleep was created for this schedule with Autosleep shown in Table 4
- Work times are shown in Table 5
- There was no travel in the schedule

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Table 4. Sleep Times for Schedule 3.

Start Sleep		End Sleep		Start Sleep		End Sleep	
Day	**Time**	**Day**	**Time**	**Day**	**Time**	**Day**	**Time**
1	22:59	2	6:58	22	22:59	23	6:58
2	22:59	3	6:58	23	22:59	24	6:58
3	22:59	4	6:58	24	22:59	25	6:58
4	22:59	5	6:58	25	22:59	26	6:58
5	22:59	6	6:58	26	22:59	27	6:58
6	22:59	7	6:58	27	22:59	28	6:58
7	22:59	8	6:58	28	22:59	29	6:58
8	23:00	9	6:59	29	23:00	30	6:59
9	23:00	10	4:59	30	23:00	31	4:59
10	22:00	11	4:59	31	22:00	32	4:59
12	7:00	12	11:58	33	7:00	33	11:58
12	22:59	13	6:58	33	22:59	34	6:58
13	22:59	14	6:58	34	22:59	35	6:58
14	22:59	15	6:58	35	22:59	36	6:58
15	23:00	16	6:59	36	23:00	37	6:59
16	23:00	17	4:59	37	23:00	38	4:59
17	22:00	18	4:59	38	22:00	39	4:59
19	7:00	19	11:58	40	7:00	40	11:58
19	22:59	20	6:58	40	22:59	41	6:58
20	22:59	21	6:58	41	22:59	42	6:58
21	22:59	22	6:58				

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Table 5. Work Times for Schedule 3.

Start Work		End Work		Start Work		End Work	
Day	**Time**	**Day**	**Time**	**Day**	**Time**	**Day**	**Time**
1	8:00	1	15:59	22	8:00	22	15:59
2	8:00	2	15:59	23	8:00	23	15:59
3	8:00	3	15:59	24	8:00	24	15:59
4	8:00	4	15:59	25	8:00	25	15:59
5	8:00	5	15:59	26	8:00	26	15:59
8	14:00	8	21:59	29	14:00	29	21:59
9	14:00	9	21:59	30	14:00	30	21:59
10	6:00	10	13:59	31	6:00	31	13:59
11	6:00	11	13:59	32	6:00	32	13:59
11	22:00	12	5:59	32	22:00	33	5:59
15	14:00	15	21:59	36	14:00	36	21:59
16	14:00	16	21:59	37	14:00	37	21:59
17	6:00	17	13:59	38	6:00	38	13:59
18	6:00	18	13:59	39	6:00	39	13:59
18	22:00	19	5:59	39	22:00	40	5:59

The PE plotted in Figure 5 shows a clear difference between the FAST™ and CORE1 version for the first minute of sleep. Figure 6 shows similar differences for the first minute awake even though the basic peaks and troughs occurred at similar time points. For the first minute of work, Figure 7 shows similar troughs to Figure 6 with somewhat different peaks. For the first minute of work, the two applications appear to be giving predictions that are less divergent than the previous two measures.

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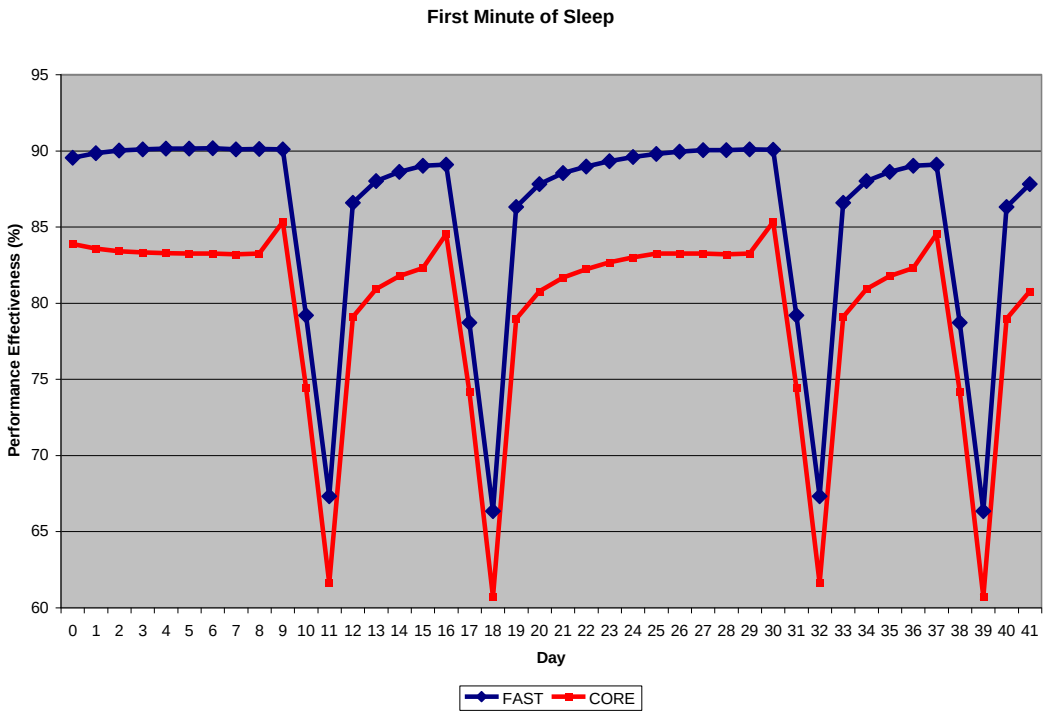

Figure 5. Plot of FAST™ and CORE1 PE projections from Schedule 3 for the first minute of sleep each day.

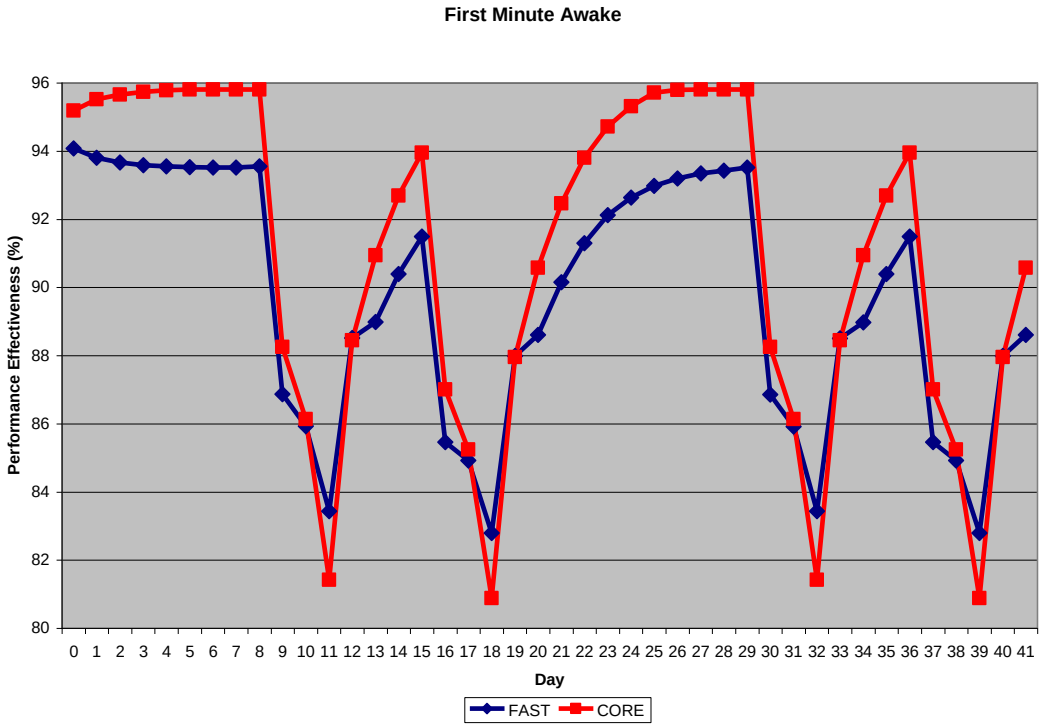

Figure 6. Plot of FAST™ and CORE1 performance effectiveness projections from Schedule 3 for the first minute awake each day.

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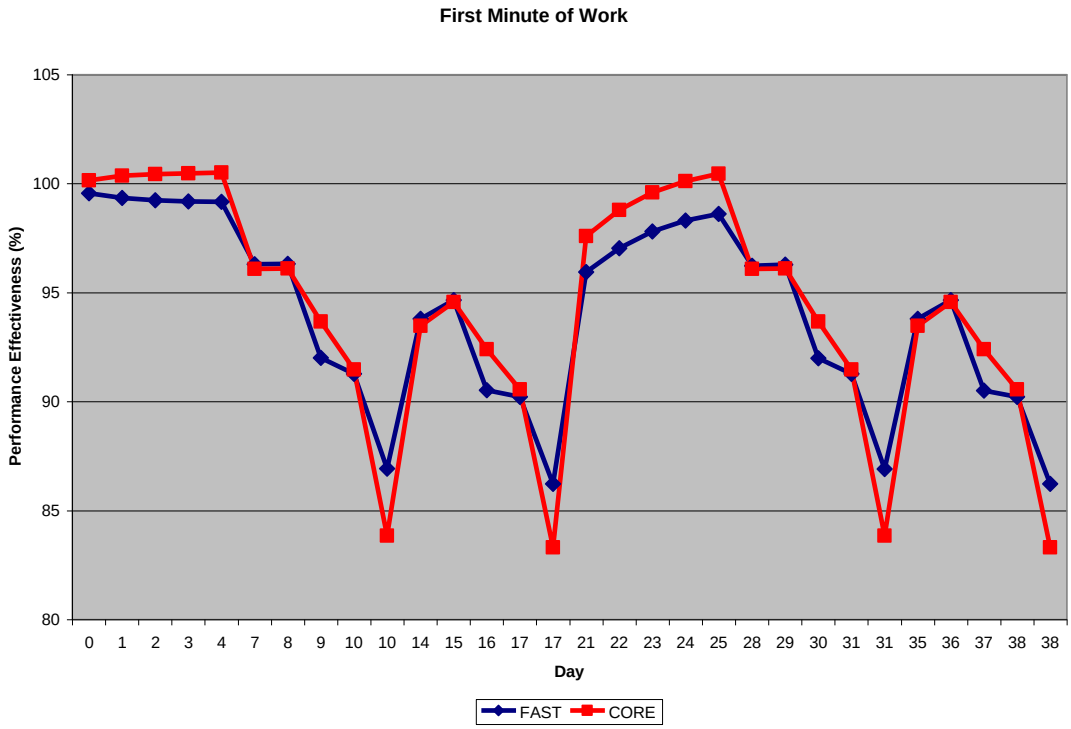

Figure 7. Plot of FAST™ and CORE1 PE projections from Schedule 3 for the first minute of work each day.

Test Schedule 4

Characteristics:

- 52-day schedule for a train operator ending in a train mishap
- The mishap was the collision of two trains
- No travel in the schedule
- Non standard sleep times are the result of an erratic work schedule

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Table 6. Sleep Times for Schedule 4.

Start Sleep		End Sleep		Start Sleep		End Sleep	
Day	**Time**	**Day**	**Time**	**Day**	**Time**	**Day**	**Time**
2	10:00	2	11:59	25	20:45	26	4:44
2	23:00	3	6:59	27	4:00	27	10:59
3	23:00	4	6:59	27	23:00	28	6:59
4	23:00	5	6:59	29	4:45	29	11:59
5	23:00	6	4:59	30	6:30	30	11:59
6	23:00	7	6:59	31	1:45	31	8:44
7	23:00	8	6:59	31	23:00	32	6:59
8	23:00	9	4:59	32	23:00	33	6:59
9	23:00	10	4:59	34	0:30	34	8:29
10	23:00	11	6:59	34	23:00	35	6:59
11	23:00	12	6:59	35	23:00	36	6:59
12	23:00	13	1:59	36	23:00	37	6:59
13	23:00	14	3:14	38	1:00	38	7:59
14	10:45	14	11:59	38	23:00	39	6:59
14	18:00	14	20:29	39	23:00	40	6:59
14	23:00	15	0:14	40	23:00	41	6:59
15	8:30	15	11:59	41	23:00	42	6:59
15	18:00	15	19:14	43	4:30	43	11:29
16	4:00	16	11:59	43	23:00	44	6:59
17	4:30	17	11:29	44	23:00	45	6:59
17	23:00	18	6:59	45	23:00	46	6:59
18	23:00	19	6:59	46	23:00	47	0:29
19	23:00	20	6:59	47	9:30	47	11:59
20	23:00	21	6:59	47	23:00	48	4:14
21	23:00	22	6:59	48	23:00	49	6:59
22	23:00	23	6:59	50	18:45	51	2:44
23	23:00	24	6:59	51	18:00	51	21:14
24	23:00	25	3:44				

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Table 7. Work Times for Schedule 4.

Start Work		End Work		Start Work		End Work	
Day	**Time**	**Day**	**Time**	**Day**	**Time**	**Day**	**Time**
1	21:00	2	8:59	28	18:45	29	3:44
6	6:00	6	19:44	29	16:00	30	5:29
8	9:15	8	10:44	30	19:00	31	0:44
9	6:00	9	17:29	33	14:00	33	23:29
10	6:00	10	21:14	34	14:00	34	20:59
11	10:45	11	19:29	35	14:00	35	20:59
13	3:00	13	11:14	36	14:00	36	21:14
14	4:15	14	9:44	37	14:00	37	23:59
15	1:15	15	7:29	42	16:00	43	3:29
15	20:15	16	2:59	47	1:30	47	8:29
16	15:00	17	3:29	48	5:15	48	10:44
21	8:15	21	17:29	50	0:15	50	12:44
22	10:00	22	19:14	51	4:00	51	11:29
23	11:45	23	21:59	52	0:15	52	7:59
24	11:30	24	19:29	51	4:00	51	11:29
25	4:45	25	14:44	52	0:15	52	7:59
26	16:30	27	2:59	52	0:15	52	7:59

Schedule 4 was taken from a train operator who was involved in a two-train collision. The operator typically acquired 8 hours of sleep when his schedule permitted, but when the schedule was tight, he often took sleep in short 1-3 hour bursts. Prior to the mishap, he missed sleep for nearly 36 hours. A plot of the first minute of sleep, Figure 8, shows the two fatigue assessment applications made predictions showing a consistent difference of about 5-9 percentage points with CORE1 showing more degradation. The first minute awake in Figure 9 shows a better correlation, but CORE1 appears to both overshoot and undershoot FAST™. The first minute of work in Figure 10 shows CORE1 closely approximating FAST™ predictions.

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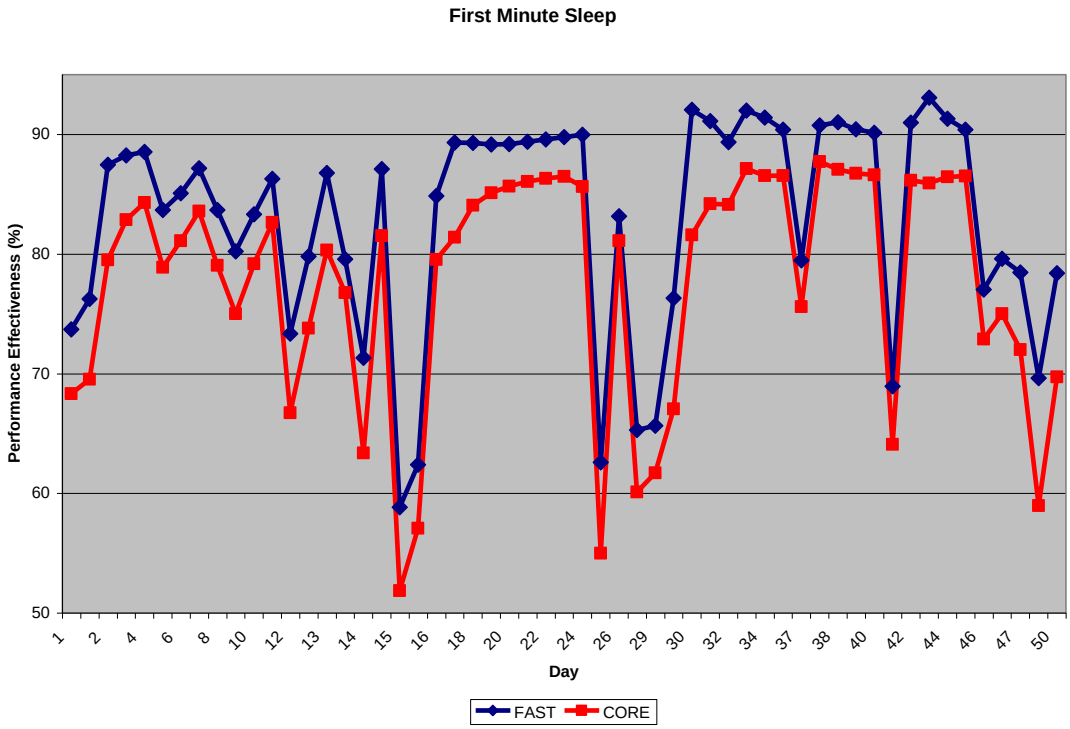

Figure 8. Plot of FAST™ and CORE1 PE projections from Schedule 4 for the first minute of sleep each day.

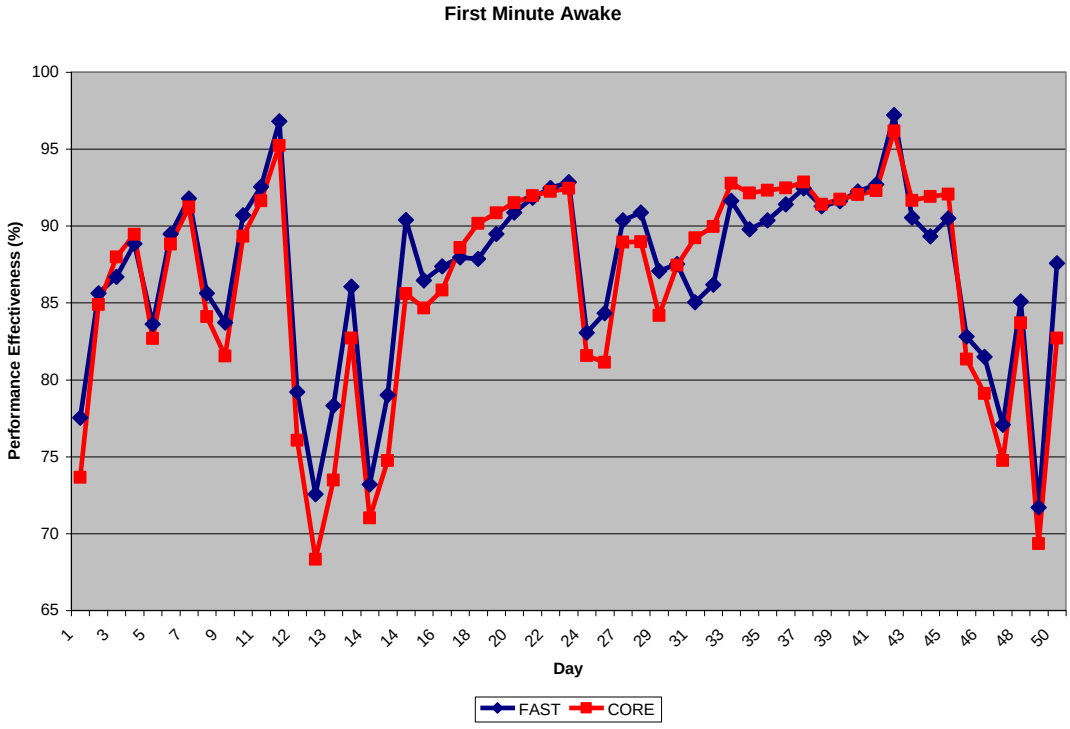

Figure 9. Plot of FAST™ and CORE1 PE projections from Schedule 4 for the first minute awake each day.

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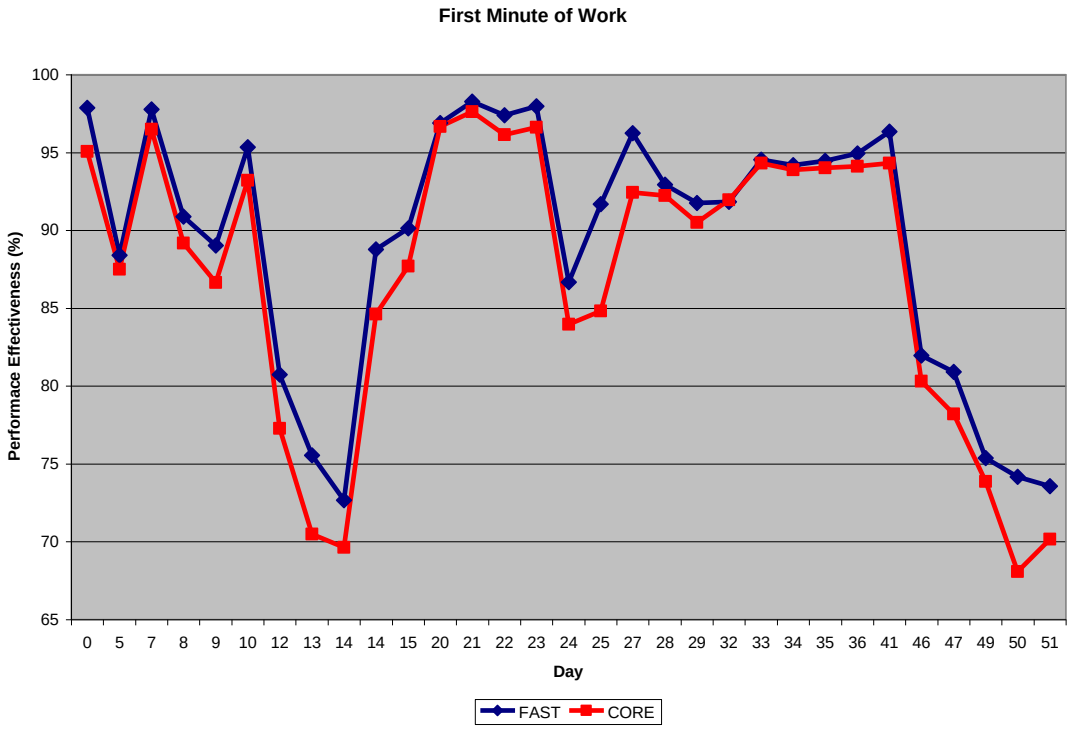

Figure 10. Plot of FAST™ and CORE1 PE projections from Schedule 4 for the first minute of work each day.

With the exception of Test Schedule 2, overall CORE1 projections appeared to generally correlate with FAST™ output in each of the tests. However, peak amplitudes were frequently off by more than 10% making the first version of the software unacceptable.

Because of the discrepancies between the projections of the first version of the web-based Core Software and FAST™ a careful comparison of the code for the two applications was undertaken. The differences were resolved, new data were generated, and the data comparison process was continued using the same schedules.

SECOND VERSION OF CORE SOFTWARE (CORE2)

Corrections to the initial Core Software. The software of FAST™ was converted from Visual Basic to C# for use in a browser. The above testing prompted a thorough examination of the coding differences between the two applications. It was determined that because of Visual Basic's less structured language, certain values were being misinterpreted by the more tightly structured C# language. A careful assessment of the author's intent for the Visual Basic code revealed what the correct interpretation should be, and these changes were incorporated into the code of the Core Software. Visual Basic allows a programmer to use of a variable in ways that are sometimes not obvious. For example, you can start with a variable declared as a floating-point number and use it later as an integer. After studying the FAST™ code, our programmer discovered that this style of programming was infrequently used. For example, a floating-point number in an

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equation was truncated where it was not supposed to be. These discrepancies were identified and changed in the new version of the Core Software.

New comparison format. Since the same schedules were used to create performance output with the new version of the web-based software, the tables of sleep and work times (Tables 1-7) are not repeated. Further, since the performance effectiveness values generated by the revised web-based version of the Core Software (CORE2) are nearly identical to those of FAST™, graphical presentation of the data would show but one line for each dependent measure. That is, the lines would fall on top of each other. Examination of the spreadsheets comparing the thousands of points, one for each minute, revealed the largest difference to be less than one percent. Instead of graphs, tables are used in the remaining comparisons to show the minute differences in a limited number of dependent measures. Because there is not a need to show several tables with nothing but rounding error differences, we limited the dependent measures to the following:

1. Last minute awake before sleep
2. First minute awake
3. Last minute of sleep before awake
4. First minute of work

Test Schedule 1

Characteristics:

- 10-day schedule
- Standard sleep from 2300-0700
- Standard work from 0900-1700
- No travel during schedule

The first and second measures for Schedule 1 are shown in Table 8 with measures three and four shown in Table 9. The data points of these tables are representative of all points generated by both applications for Scenario 1. The differences appear to be insignificant and likely due to rounding differences for software written in different programming languages.

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Table 8. Comparison of FAST™ and CORE2 PE for last and first minute awake from Schedule 1.

Dependent Meas.		Last Minute Awake			First Minute Awake		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Sat	1/1/2000	90.17739	90.17724	0.00015			
Sun	1/2/2000	90.17402	90.17627	-0.00225	93.50633	93.50662	-0.00029
Mon	1/3/2000	90.17212	90.17685	-0.00473	93.50935	93.50730	0.00205
Tue	1/4/2000	90.17072	90.17685	-0.00613	93.51051	93.50730	0.00321
Wed	1/5/2000	90.16991	90.17685	-0.00694	93.51119	93.50730	0.00389
Thu	1/6/2000	90.16946	90.17685	-0.00739	93.51157	93.50730	0.00427
Fri	1/7/2000	90.16919	90.17685	-0.00766	93.51180	93.50730	0.00450
Sat	1/8/2000	90.16903	90.17685	-0.00782	93.51192	93.50730	0.00462
Sun	1/9/2000	90.16894	90.17685	-0.00791	93.51200	93.50730	0.00470
Mon	1/10/2000				93.51204	93.50730	0.00474

Table 9. Comparison of FAST™ and CORE2 PE for last minute of sleep and first minute of work from Schedule 1.

Dependent Meas.		Last Minute of Sleep			First Minute of Work		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Sun	1/2/2000	98.15327	98.15353	-0.00026	99.66575	99.66573	0.00002
Mon	1/3/2000	98.15604	98.15417	0.00187	99.66752	99.66633	0.00119
Tue	1/4/2000	98.15715	98.15419	0.00296	99.66820	99.66633	0.00187
Wed	1/5/2000	98.15776	98.15419	0.00357	99.66858	99.66633	0.00225
Thu	1/6/2000	98.15812	98.15419	0.00393	99.66880	99.66633	0.00247
Fri	1/7/2000	98.15833	98.15419	0.00414	99.66894	99.66633	0.00261
Sat	1/8/2000	98.15844	98.15419	0.00425	99.66901	99.66633	0.00268
Sun	1/9/2000	98.15851	98.15419	0.00432	99.66904	99.66633	0.00271
Mon	1/10/2000	98.15855	98.15419	0.00436	99.66907	99.66633	0.00274

Test Schedule 2

Characteristics:

- 14-day schedule
- Travel from New York to Rome
- Six hour phase advance on the third day follows the location change shown in Table 2
- Sleep and work times are affected by the transmeridian travel as shown in Table 3

The last and first minute awake measures for Schedule 2 are shown in Table 10 with the last minute of sleep and first minute of work measures shown in Table 11. The data

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points shown in these tables are representative of the thousands of minute-by-minute points generated by both applications for Scenario 2. Again, the differences appear to be insignificant.

Table 10. Comparison of FAST™ and CORE2 PE for last and first minute awake from Schedule 2.

Dependent Meas.		Last Minute Awake			First Minute Awake		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Sat	1/1/2000	89.93969	89.93960	0.00009			
Sun	1/2/2000	90.08810	90.08788	0.00022	93.64751	93.64761	-0.00010
Mon	1/3/2000	98.18960	98.18966	-0.00006	93.58154	93.58166	-0.00012
Tue	1/4/2000	87.99393	87.99584	-0.00191	87.86585	87.86527	0.00058
Wed	1/5/2000	85.90559	85.90959	-0.00400	81.81758	81.81659	0.00099
Thu	1/6/2000	84.97821	84.98541	-0.00720	78.86784	78.86813	-0.00029
Fri	1/7/2000	87.48132	87.48595	-0.00463	78.99181	78.99469	-0.00288
Sat	1/8/2000	87.95483	87.95832	-0.00349	79.18335	79.18773	-0.00438
Sun	1/9/2000	90.09346	90.09663	-0.00317	80.60458	80.60866	-0.00408
Mon	1/10/2000	89.21985	89.22250	-0.00265	84.04427	84.04662	-0.00235
Tue	1/11/2000	88.54440	88.54657	-0.00217	86.51425	86.51451	-0.00026
Wed	1/12/2000	88.55377	88.55490	-0.00113	88.99552	88.99545	0.00007
Thu	1/13/2000	88.87450	88.87510	-0.00060	90.64423	90.64417	0.00006
Fri	1/14/2000				91.69424	91.69421	0.00003

Table 11. Comparison of FAST™ and CORE2 PE for last minute of sleep and first minute of work from Schedule 2.

Dependent Meas.		Last Minute of Sleep			First Minute of Work		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Sun	1/2/2000	98.28281	98.28290	-0.00009	99.74583	99.74589	-0.00006
Mon	1/3/2000	98.22258	98.22268	-0.00010			
Tue	1/4/2000	92.84550	92.84493	0.00057	88.37655	88.37626	0.00029
Wed	1/5/2000	86.85089	86.84988	0.00101	82.89704	82.89724	-0.00020
Thu	1/6/2000	83.90286	83.90312	-0.00026	80.80824	80.81086	-0.00262
Fri	1/7/2000	84.00414	84.00697	-0.00283	81.96823	81.97360	-0.00537
Sat	1/8/2000	84.17644	84.18077	-0.00433	83.10339	83.10937	-0.00598
Sun	1/9/2000	85.56865	85.57269	-0.00404	85.36580	85.37059	-0.00479
Mon	1/10/2000	88.95193	88.95428	-0.00235	89.48090	89.48331	-0.00241
Tue	1/11/2000	91.37251	91.37280	-0.00029	92.31186	92.31196	-0.00010
Wed	1/12/2000	93.79042	93.79037	0.00005	94.84321	94.84314	0.00007
Thu	1/13/2000	95.39063	95.39059	0.00004	96.42673	96.42670	0.00003
Fri	1/14/2000	96.40730	96.40726	0.00004	97.41744	97.41742	0.00002

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Test Schedule 3

Characteristics:

- 42-day, counterclockwise shift rotation schedule
- No work on weekends
- Two-day shift rotations start after working a day-time shift for a week
- Sleep was created for this schedule with Autosleep shown in Table 4
- Work times are shown in Table 5
- There was no travel in the schedule

The last and first minute awake measures for Schedule 3 are shown in Table 12 with the last minute of sleep and the first minute of work measures shown in Table 13. The data points shown in these tables are representative of all points generated by both applications for Scenario 3. Some of the largest differences between CORE2 and FAST™ are shown for the last minute awake in Table 12, 0.62185%, and the first minute of work in Table 13, -0.44889%. The differences appear to be insignificant, unsystematic, and likely due to differences in the programming languages between CORE2 and FAST™.

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Table 12. Comparison of FAST™ and CORE2 PE for last and first minute awake from Schedule 3.

Dependent Meas.		Last Minute Awake			First Minute Awake		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Mon	1/1/2001	90.24115	89.61930	0.62185			
Tue	1/2/2001	90.23844	89.92004	0.31840	93.50686	93.80367	-0.29681
Wed	1/3/2001	90.23640	90.07282	0.16358	93.50938	93.66155	-0.15217
Thu	1/4/2001	90.23502	90.15083	0.08419	93.51054	93.58886	-0.07832
Fri	1/5/2001	90.23423	90.19101	0.04322	93.51120	93.55162	-0.04042
Sat	1/6/2001	90.23377	90.21112	0.02265	93.51158	93.53265	-0.02107
Sun	1/7/2001	90.23351	90.22179	0.01172	93.51180	93.52317	-0.01137
Mon	1/8/2001	90.15110	90.14288	0.00822	93.51192	93.51688	-0.00496
Tue	1/9/2001	90.18209	90.17748	0.00461	93.54734	93.55141	-0.00407
Wed	1/10/2001	90.12708	90.12670	0.00038	86.86629	86.86875	-0.00246
Thu	1/11/2001				85.92694	85.92938	-0.00244
Fri	1/12/2001	67.27662	67.27896	-0.00234	83.43323	83.43401	-0.00078
Fri	1/12/2001	79.27286	79.27032	0.00254			
Sat	1/13/2001	86.65496	86.65105	0.00391	88.50313	88.50614	-0.00301
Sun	1/14/2001	88.07978	88.07861	0.00117	88.97200	88.97538	-0.00338
Mon	1/15/2001	88.67849	88.67837	0.00012	90.38794	90.39020	-0.00226
Tue	1/16/2001	89.07047	89.07072	-0.00025	91.48595	91.48742	-0.00147
Wed	1/17/2001	89.13809	89.13865	-0.00056	85.46131	85.46230	-0.00099
Thu	1/18/2001				84.91783	84.91895	-0.00112
Fri	1/19/2001	66.30519	66.30643	-0.00124	82.78648	82.78692	-0.00044
Fri	1/19/2001	78.78384	78.78181	0.00203			
Sat	1/20/2001	86.37190	86.36850	0.00340	87.99162	87.99393	-0.00231
Sun	1/21/2001	87.86287	87.86184	0.00103	88.60892	88.61167	-0.00275
Mon	1/22/2001	88.60366	88.60346	0.00020	90.15263	90.15442	-0.00179
Tue	1/23/2001	89.01207	89.01221	-0.00014	91.29853	91.29971	-0.00118
Wed	1/24/2001	89.37189	89.37218	-0.00029	92.11499	92.11575	-0.00076
Thu	1/25/2001	89.65321	89.65342	-0.00021	92.64058	92.64088	-0.00030
Fri	1/26/2001	89.85992	89.86003	-0.00011	92.97865	92.97886	-0.00021
Sat	1/27/2001	90.00574	90.00668	-0.00094	93.19607	93.19608	-0.00001
Sun	1/28/2001	90.10716	90.10788	-0.00072	93.33608	93.33611	-0.00003
Mon	1/29/2001	90.09263	90.09263	0.00000	93.42713	93.42673	0.00040
Tue	1/30/2001	90.16294	90.16351	-0.00057	93.51610	93.51631	-0.00021
Wed	1/31/2001	90.11816	90.11805	0.00011	86.85284	86.85269	0.00015
Thu	2/1/2001				85.91833	85.91856	-0.00023
Fri	2/2/2001	67.26837	67.26861	-0.00024	83.42808	83.42805	0.00003
Fri	2/2/2001	79.26945	79.26740	0.00205			
Sat	2/3/2001	86.65311	86.64967	0.00344	88.49880	88.50049	-0.00169
Sun	2/4/2001	88.07820	88.07700	0.00120	88.96884	88.97103	-0.00219
Mon	2/5/2001	88.67728	88.67695	0.00033	90.38586	90.38730	-0.00144
Tue	2/6/2001	89.06957	89.06958	-0.00001	91.48458	91.48550	-0.00092
Wed	2/7/2001	89.13735	89.13761	-0.00026	85.46034	85.46091	-0.00057
Thu	2/8/2001				84.91714	84.91791	-0.00077
Fri	2/9/2001	66.30453	66.30544	-0.00091	82.78603	82.78620	-0.00017
Sat	2/10/2001	86.37191	86.36834	0.00357	87.99128	87.99338	-0.00210
Sun	2/11/2001	87.86296	87.86185	0.00111	88.60869	88.61131	-0.00262

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Table 13. Comparison of FAST™ and CORE2 PE for last minute of sleep and first minute of work from Schedule 3.

Dependent Meas.		Last Minute of Sleep			First Minute of Work		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Mon	1/1/2001				99.11430	99.56319	-0.44889
Tue	1/2/2001	98.15375	98.42493	-0.27118	99.11945	99.35299	-0.23354
Wed	1/3/2001	98.15607	98.29562	-0.13955	99.12154	99.24241	-0.12087
Thu	1/4/2001	98.15717	98.22928	-0.07211	99.12250	99.18496	-0.06246
Fri	1/5/2001	98.15777	98.19505	-0.03728	99.12305	99.15539	-0.03234
Sat	1/6/2001	98.15813	98.17756	-0.01943			
Sun	1/7/2001	98.15833	98.16881	-0.01048			
Mon	1/8/2001	98.15844	98.16303	-0.00459	96.30136	96.30296	-0.00160
Tue	1/9/2001	98.19083	98.19457	-0.00374	96.31747	96.31831	-0.00084
Wed	1/10/2001	91.78392	91.78632	-0.00240	92.00345	92.00649	-0.00304
Thu	1/11/2001	90.83909	90.84148	-0.00239	91.27525	91.27826	-0.00301
Thu	1/11/2001				86.91663	86.91592	0.00071
Fri	1/12/2001	88.38576	88.38653	-0.00077			
Sat	1/13/2001	93.25906	93.26195	-0.00289			
Sun	1/14/2001	93.75475	93.75801	-0.00326			
Mon	1/15/2001	95.13873	95.14092	-0.00219	93.80188	93.80321	-0.00133
Tue	1/16/2001	96.20457	96.20599	-0.00142	94.65514	94.65614	-0.00100
Wed	1/17/2001	90.39220	90.39317	-0.00097	90.51434	90.51545	-0.00111
Thu	1/18/2001	89.83940	89.84050	-0.00110	90.21617	90.21751	-0.00134
Thu	1/18/2001				86.22877	86.22839	0.00038
Fri	1/19/2001	87.74339	87.74382	-0.00043			
Sat	1/20/2001	92.75851	92.76073	-0.00222			
Sun	1/21/2001	93.39896	93.40160	-0.00264			
Mon	1/22/2001	94.90875	94.91048	-0.00173	95.94356	95.94524	-0.00168
Tue	1/23/2001	96.02301	96.02415	-0.00114	97.04150	97.04260	-0.00110
Wed	1/24/2001	96.81345	96.81416	-0.00071	97.81046	97.81114	-0.00068
Thu	1/25/2001	97.32180	97.32209	-0.00029	98.30509	98.30537	-0.00028
Fri	1/26/2001	97.64874	97.64894	-0.00020	98.62393	98.62415	-0.00022
Sat	1/27/2001	97.85906	97.85909	-3E-05			
Sun	1/28/2001	97.99455	97.99458	-3E-05			
Mon	1/29/2001	98.08128	98.08092	0.00036	96.23186	96.23173	0.00013
Tue	1/30/2001	98.16245	98.16264	-0.00019	96.29234	96.29234	0
Wed	1/31/2001	91.77067	91.77052	0.00015	91.98896	91.98882	0.00014
Thu	2/1/2001	90.83057	90.83080	-0.00023	91.26607	91.26646	-0.00039
Thu	2/1/2001				86.91145	86.91078	0.00067
Fri	2/2/2001	88.38064	88.38061	3E-05			
Sat	2/3/2001	93.25484	93.25645	-0.00161			
Sun	2/4/2001	93.75166	93.75377	-0.00211			

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Test Schedule 4

Characteristics:

- 52-day schedule for a train operator ending in a train mishap
- The mishap was the collision of two trains
- No travel in the schedule
- Non standard sleep times resulting from an erratic work schedule

The last and first minute awake measures for Schedule 4 are shown in Table 14 with the last minute of sleep and the first minute of work measures shown in Table 15. The data points of these tables are representative of all points generated by both applications for Scenario 4. As a point of interest, the engineer started his work shift prior to the mishap with a PE value of 74%, Table 15 on 2/21/2004. At the time of the accident, his PE was less the 62% (not shown in table). Again, the differences between the two programs appear to be insignificant.

Table 14. Comparison of FAST™ and CORE2 PE for last and first minute awake from Schedule 4.

Dependent Meas.		Last Minute Awake			First Minute Awake		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Fri	1/2/2004	73.69163	73.69163	0.00000			
Fri	1/2/2004	76.30443	76.30320	0.00123	77.51918	77.51919	-0.00001
Sat	1/3/2004	87.50912	87.50693	0.00219	85.61922	85.62067	-0.00145
Sun	1/4/2004	88.30235	88.30170	0.00065	86.68018	86.68214	-0.00196
Mon	1/5/2004	88.60458	88.60449	0.00009	88.83073	88.83208	-0.00135
Tue	1/6/2004	83.75427	83.75454	-0.00027	83.60858	83.60944	-0.00086
Wed	1/7/2004	85.16464	85.16457	0.00007	89.47795	89.47879	-0.00084
Thu	1/8/2004	87.24010	87.24013	-0.00003	91.78574	91.78629	-0.00055
Fri	1/9/2004	83.75146	83.75153	-0.00007	85.62943	85.62977	-0.00034
Sat	1/10/2004	80.30466	80.30477	-0.00011	83.71000	83.71030	-0.00030
Sun	1/11/2004	83.37723	83.37733	-0.00010	90.68758	90.68779	-0.00021
Mon	1/12/2004	86.35214	86.35220	-0.00006	92.54987	92.54999	-0.00012
Tue	1/13/2004	73.42200	73.42210	-0.00010	79.20998	79.21006	-0.00008
Wed	1/14/2004	79.81280	79.81299	-0.00019	72.55933	72.55943	-0.00010
Wed	1/14/2004	86.74080	86.74143	-0.00063	78.31586	78.31600	-0.00014
Wed	1/14/2004	79.66622	79.66511	0.00111	86.04544	86.04500	0.00044
Thu	1/15/2004	71.31468	71.31557	-0.00089	73.17825	73.17737	0.00088
Thu	1/15/2004	87.07670	87.07771	-0.00101	78.99375	78.99393	-0.00018
Thu	1/15/2004				85.50927	85.50949	-0.00022
Fri	1/16/2004	58.83827	58.83870	-0.00043	86.44967	86.44942	0.00025
Sat	1/17/2004	62.39096	62.39148	-0.00052	87.38006	87.37908	0.00098
Sat	1/17/2004	84.93193	84.92500	0.00693			
Sun	1/18/2004	89.38913	89.38338	0.00575	87.95602	87.96042	-0.00440
Mon	1/19/2004	89.35497	89.35323	0.00174	87.83222	87.83738	-0.00516
Tue	1/20/2004	89.22559	89.22535	0.00024	89.48136	89.48495	-0.00359
Wed	1/21/2004	89.25824	89.25859	-0.00035	90.86380	90.86623	-0.00243

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Dependent Meas.		Last Minute Awake			First Minute Awake		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Thu	1/22/2004	89.44929	89.44976	-0.00047	91.83475	91.83633	-0.00158
Fri	1/23/2004	89.66058	89.66112	-0.00054	92.46056	92.46159	-0.00103
Sat	1/24/2004	89.84263	89.84296	-0.00033	92.86306	92.86371	-0.00065
Sun	1/25/2004	89.99337	89.99379	-0.00042	83.05505	83.05554	-0.00049
Mon	1/26/2004				84.33176	84.33257	-0.00081
Tue	1/27/2004	62.57320	62.57474	-0.00154	88.63964	88.63927	0.00037
Tue	1/27/2004	83.24174	83.23598	0.00576			
Wed	1/28/2004				90.37003	90.37368	-0.00365
Thu	1/29/2004	65.29173	65.29198	-0.00025	90.88000	90.87880	0.00120
Fri	1/30/2004				87.07378	87.07176	0.00202
Sat	1/31/2004	76.38966	76.37315	0.01651	87.50317	87.50909	-0.00592
Sat	1/31/2004	92.08941	92.08238	0.00703			
Sun	2/1/2004	91.15131	91.15075	0.00056	85.03180	85.03970	-0.00790
Mon	2/2/2004				86.17938	86.18745	-0.00807
Tue	2/3/2004	82.73487	82.73067	0.00420	91.61659	91.62271	-0.00612
Tue	2/3/2004	92.05651	92.05537	0.00114			
Wed	2/4/2004	91.46796	91.46856	-0.00060	89.76778	89.77271	-0.00493
Thu	2/5/2004	90.44686	90.44778	-0.00092	90.36954	90.37286	-0.00332
Fri	2/6/2004				91.41220	91.41439	-0.00219
Sat	2/7/2004	79.54833	79.54929	-0.00096	92.44851	92.44986	-0.00135
Sat	2/7/2004	90.81990	90.82060	-0.00070			
Sun	2/8/2004	91.07545	91.07577	-0.00032	91.28060	91.28176	-0.00116
Mon	2/9/2004	90.47749	90.47776	-0.00027	91.60709	91.60783	-0.00074
Tue	2/10/2004	90.18804	90.18833	-0.00029	92.23826	92.23881	-0.00055
Wed	2/11/2004				92.70465	92.70497	-0.00032
Thu	2/12/2004	68.92368	68.92396	-0.00028	92.55322	92.55338	-0.00016
Thu	2/12/2004	91.03803	91.03689	0.00114			
Fri	2/13/2004	93.11156	93.11057	0.00099	90.54367	90.54552	-0.00185
Sat	2/14/2004	91.37703	91.37682	0.00021	89.33224	89.33373	-0.00149
Sun	2/15/2004	90.46864	90.46869	-0.00005	90.49357	90.49459	-0.00102
Mon	2/16/2004	77.00135	77.00210	-0.00075	82.79808	82.79813	-0.00005
Mon	2/16/2004	79.67215	79.67159	0.00056	81.49096	81.49145	-0.00049
Tue	2/17/2004	78.53182	78.53189	-0.00007	77.07245	77.07319	-0.00074
Wed	2/18/2004				85.08425	85.08565	-0.00140
Thu	2/19/2004	69.61806	69.61920	-0.00114			
Fri	2/20/2004	78.34732	78.35152	-0.00420	71.68479	71.68562	-0.00083
Fri	2/20/2004				82.61905	82.61832	0.00073

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Table 15. Comparison of FAST™ and CORE2 PE for last minute of sleep and first minute of work from Schedule 4.

Dependent Meas.		Last Minute of Sleep			First Minute of Work		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Thu	1/1/2004				97.86626	97.86626	0.00000
Fri	1/2/2004	82.57455	82.57455	0.00000			
Sat	1/3/2004	90.47451	90.47592	-0.00141			
Sun	1/4/2004	91.52749	91.52938	-0.00189			
Mon	1/5/2004	93.62874	93.63004	-0.00130			
Tue	1/6/2004	88.56032	88.56116	-0.00084	88.41396	88.41498	-0.00102
Wed	1/7/2004	94.23886	94.23967	-0.00081			
Thu	1/8/2004	96.45840	96.45892	-0.00052	97.76994	97.77034	-0.00040
Fri	1/9/2004	90.54858	90.54891	-0.00033	90.88580	90.88619	-0.00039
Sat	1/10/2004	88.64700	88.64730	-0.00030	89.01942	89.01976	-0.00034
Sun	1/11/2004	95.38196	95.38216	-0.00020	95.35115	95.35130	-0.00015
Mon	1/12/2004	97.16863	97.16874	-0.00011			
Tue	1/13/2004	84.27356	84.27364	-0.00008	80.73091	80.73101	-0.00010
Wed	1/14/2004	77.62017	77.62026	-0.00009	75.54720	75.54750	-0.00030
Wed	1/14/2004	83.33318	83.33333	-0.00015			
Wed	1/14/2004	90.96787	90.96745	0.00042			
Thu	1/15/2004	78.28695	78.28607	0.00088	72.65913	72.65846	0.00067
Thu	1/15/2004	83.97604	83.97621	-0.00017	88.77426	88.77377	0.00049
Thu	1/15/2004	90.38652	90.38675	-0.00023			
Fri	1/16/2004	91.24361	91.24335	0.00026	90.12574	90.12624	-0.00050
Sat	1/17/2004	92.16851	92.16757	0.00094			
Sun	1/18/2004	92.74571	92.74993	-0.00422			
Mon	1/19/2004	92.66276	92.66776	-0.00500			
Tue	1/20/2004	94.27023	94.27372	-0.00349			
Wed	1/21/2004	95.60949	95.61182	-0.00233	96.88406	96.88627	-0.00221
Thu	1/22/2004	96.54668	96.54821	-0.00153	98.27170	98.27287	-0.00117
Fri	1/23/2004	97.15013	97.15114	-0.00101	97.40405	97.40480	-0.00075
Sat	1/24/2004	97.53825	97.53889	-0.00064	97.95610	97.95659	-0.00049
Sun	1/25/2004	88.05299	88.05348	-0.00049	86.67231	86.67281	-0.00050
Mon	1/26/2004	89.26115	89.26195	-0.00080	91.67228	91.67394	-0.00166
Tue	1/27/2004	93.43594	93.43560	0.00034			
Wed	1/28/2004	95.07685	95.08029	-0.00344	96.23190	96.23480	-0.00290
Thu	1/29/2004	95.58203	95.58092	0.00111	92.93190	92.93314	-0.00124
Fri	1/30/2004	91.92841	91.92648	0.00193	91.75258	91.75631	-0.00373
Sat	1/31/2004	92.30656	92.31224	-0.00568			
Sun	2/1/2004	89.94059	89.94830	-0.00771			
Mon	2/2/2004	91.06175	91.06964	-0.00789	91.82639	91.83068	-0.00429
Tue	2/3/2004	96.27854	96.28436	-0.00582	94.52997	94.53284	-0.00287
Wed	2/4/2004	94.56900	94.57378	-0.00478	94.18501	94.18792	-0.00291
Thu	2/5/2004	95.15182	95.15505	-0.00323	94.45319	94.45546	-0.00227
Fri	2/6/2004	96.15227	96.15439	-0.00212	94.94123	94.94286	-0.00163
Sat	2/7/2004	97.11887	97.12018	-0.00131			
Sun	2/8/2004	96.03208	96.03321	-0.00113			
Mon	2/9/2004	96.34706	96.34779	-0.00073			
Tue	2/10/2004	96.94846	96.94901	-0.00055			

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Dependent Meas.		Last Minute of Sleep			First Minute of Work		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Wed	2/11/2004	97.39272	97.39304	-0.00032	96.34255	96.34284	-0.00029
Thu	2/12/2004	97.22291	97.22307	-0.00016			
Fri	2/13/2004	95.31711	95.31887	-0.00176			
Sat	2/14/2004	94.15794	94.15939	-0.00145			
Sun	2/15/2004	95.27277	95.27378	-0.00101			
Mon	2/16/2004	87.88034	87.88039	-0.00005	81.96500	81.96511	-0.00011
Mon	2/16/2004	86.49751	86.49799	-0.00048			
Tue	2/17/2004	82.08887	82.08961	-0.00074	80.92321	80.92426	-0.00105
Wed	2/18/2004	89.93004	89.93140	-0.00136			
Thu	2/19/2004				75.37611	75.37297	0.00314
Fri	2/20/2004	76.73950	76.74032	-0.00082	74.16930	74.17168	-0.00238
Fri	2/20/2004	87.56767	87.56699	0.00068			
Sat	2/21/2004				73.57406	73.57032	0.00374

CORE SOFTWARE AFTER ADDING THE PHARMACEUTICAL FATIGUE COUNTERMEASURES ALGORITHM (CORE3)

Initial testing of the software after the addition of the pharmaceutical fatigue countermeasures algorithm revealed some differences with FAST™ predictions when no countermeasures were enabled. These results prompted a thorough examination of the code changes and the programmer discovered some problems. These discrepancies were identified and corrected in a revised version of the Core Software (CORE3).

Comparison format. The same schedules were used to create performance output with the new version of the core software. The tables of sleep and work times are shown in Tables 1-7. Examination of the spreadsheets comparing the thousands of points, one for each minute, revealed the largest difference to be less than one percent. Since the lines would fall on top of each other, graphs are not shown. Tables are used to show the minute differences in a limited number of dependent measures in the comparisons. Because there is not a need to show several tables with nothing but rounding error differences, we limited the dependent measures to the following:

1. Last minute awake before sleep
2. First minute awake
3. Last minute of sleep before awake
4. First minute of work

Test Schedule 1

Characteristics:

- 10-day schedule
- Standard sleep from 2300-0700

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- Standard work from 0900-1700
- No travel during schedule

The first and second measures for Schedule 1 are shown in Table 16 with measures three and four shown in Table 17. The data points of these tables are representative of all points generated by both applications for Scenario 1. The differences appear to be insignificant and likely due to rounding differences for software written in different programming languages. The largest difference was 0.064% for the last minute awake on 1/1/2000.

Table 16. Comparison of FAST™ and CORE3 PE for last and first minute awake from Schedule 1.

Dependent Meas.		Last Minute Awake			First Minute Awake		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Sat	1/1/2000	90.24115	90.17724	0.06391			
Sun	1/2/2000	90.23844	90.17627	0.06217	93.50686	93.50662	0.00024
Mon	1/3/2000	90.23640	90.17685	0.05955	93.50938	93.50730	0.00208
Tue	1/4/2000	90.23502	90.17685	0.05817	93.51054	93.50730	0.00324
Wed	1/5/2000	90.23423	90.17685	0.05738	93.51120	93.50730	0.00390
Thu	1/6/2000	90.23377	90.17685	0.05692	93.51158	93.50730	0.00428
Fri	1/7/2000	90.23351	90.17685	0.05666	93.51180	93.50730	0.00450
Sat	1/8/2000	90.23336	90.17685	0.05651	93.51192	93.50730	0.00462
Sun	1/9/2000	90.23328	90.17685	0.05643	93.51200	93.50730	0.00470
Mon	1/10/2000				93.51204	93.50730	0.00474

Table 17. Comparison of FAST™ and CORE3 PE for last minute of sleep and first minute of work from Schedule 1.

Dependent Meas.		Last Minute of Sleep			First Minute of Work		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Sun	1/2/2000	98.15375	98.15353	0.00022	99.66592	99.66573	0.00019
Mon	1/3/2000	98.15607	98.15417	0.00190	99.66753	99.66633	0.00120
Tue	1/4/2000	98.15717	98.15419	0.00298	99.66821	99.66633	0.00188
Wed	1/5/2000	98.15777	98.15419	0.00358	99.66859	99.66633	0.00226
Thu	1/6/2000	98.15813	98.15419	0.00394	99.66881	99.66633	0.00248
Fri	1/7/2000	98.15833	98.15419	0.00414	99.66894	99.66633	0.00261
Sat	1/8/2000	98.15844	98.15419	0.00425	99.66901	99.66633	0.00268
Sun	1/9/2000	98.15851	98.15419	0.00432	99.66904	99.66633	0.00271
Mon	1/10/2000	98.15855	98.15419	0.00436	99.66907	99.66633	0.00274

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Test Schedule 2

Characteristics:

- 14-day schedule
- Travel from New York to Rome
- Six-hour phase advance on the third day follows the location change shown in Table 2
- Sleep and work times are affected by the transmeridian travel as shown in Table 3

The last and first minute awake measures for Schedule 2 are shown in Table 18 with the last minute of sleep and first minute of work measures shown in Table 19. The data points shown in these tables are representative of the thousands of minute-by-minute points generated by both applications for Scenario 2. Again, the differences appear to be insignificant.

Table 18. Comparison of FAST™ and CORE3 PE for last and first minute awake from Schedule 2.

Dependent Meas.		Last Minute Awake			First Minute Awake		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Sat	1/1/2000	89.93969	89.93960	0.00009			
Sun	1/2/2000	90.08810	90.08788	0.00022	93.64751	93.64761	-0.00010
Mon	1/3/2000	98.18960	98.18966	-0.00006	93.58154	93.58166	-0.00012
Tue	1/4/2000	87.99393	87.99584	-0.00191	87.86585	87.86527	0.00058
Wed	1/5/2000	85.90559	85.90959	-0.00400	81.81758	81.81659	0.00099
Thu	1/6/2000	84.97821	84.98541	-0.00720	78.86784	78.86813	-0.00029
Fri	1/7/2000	87.48132	87.48595	-0.00463	78.99181	78.99469	-0.00288
Sat	1/8/2000	87.95483	87.95832	-0.00349	79.18335	79.18773	-0.00438
Sun	1/9/2000	90.09346	90.09663	-0.00317	80.60458	80.60866	-0.00408
Mon	1/10/2000	89.21985	89.22250	-0.00265	84.04427	84.04662	-0.00235
Tue	1/11/2000	88.54440	88.54657	-0.00217	86.51425	86.51451	-0.00026
Wed	1/12/2000	88.55377	88.55490	-0.00113	88.99552	88.99545	0.00007
Thu	1/13/2000	88.87450	88.87510	-0.00060	90.64423	90.64417	0.00006
Fri	1/14/2000				91.69424	91.69421	0.00003

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Table 19. Comparison of FAST™ and CORE3 PE for last minute of sleep and first minute of work from Schedule 2.

Dependent Meas.		Last Minute of Sleep			First Minute of Work		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Sun	1/2/2000	98.28281	98.28290	-0.00009	99.74583	99.74589	-0.00006
Mon	1/3/2000	98.22258	98.22268	-0.00010			
Tue	1/4/2000	92.84550	92.84493	0.00057	88.37655	88.37626	0.00029
Wed	1/5/2000	86.85089	86.84988	0.00101	82.89704	82.89724	-0.00020
Thu	1/6/2000	83.90286	83.90312	-0.00026	80.80824	80.81086	-0.00262
Fri	1/7/2000	84.00414	84.00697	-0.00283	81.96823	81.97360	-0.00537
Sat	1/8/2000	84.17644	84.18077	-0.00433	83.10339	83.10937	-0.00598
Sun	1/9/2000	85.56865	85.57269	-0.00404	85.36580	85.37059	-0.00479
Mon	1/10/2000	88.95193	88.95428	-0.00235	89.48090	89.48331	-0.00241
Tue	1/11/2000	91.37251	91.37280	-0.00029	92.31186	92.31196	-0.00010
Wed	1/12/2000	93.79042	93.79037	0.00005	94.84321	94.84314	0.00007
Thu	1/13/2000	95.39063	95.39059	0.00004	96.42673	96.42670	0.00003
Fri	1/14/2000	96.40730	96.40726	0.00004	97.41744	97.41742	0.00002

Test Schedule 3

Characteristics:

- 42-day, counterclockwise shift rotation schedule
- No work on weekends
- Two-day shift rotations start after working a day-time shift for a week
- Sleep was created for this schedule with Autosleep shown in Table 4
- Work times are shown in Table 5
- There was no travel in the schedule

The last and first minute awake measures for Schedule 3 are shown in Table 20 with the last minute of sleep and the first minute of work measures shown in Table 21. The data points shown in these tables are representative of all points generated by both applications for Scenario 3. Some of the largest differences between CORE3 and FAST™ are shown for the last minute awake in Table 20, -0.06045%, and the last minute of sleep in Table 21, -0.00274%. The differences appear to be insignificant, unsystematic, and likely due to differences in the programming languages between CORE3 and FAST™.

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Table 20. Comparison of FAST™ and CORE3 PE for last and first minute awake from Schedule 3.

Dependent Meas.		Last Minute Awake			First Minute Awake		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Mon	1/1/2001	89.61932	89.61930	2E-05			
Tue	1/2/2001	89.92002	89.92004	-2E-05	93.80367	93.80367	0.0000
Wed	1/3/2001	90.07286	90.07282	4E-05	93.66157	93.66155	2E-05
Thu	1/4/2001	90.15101	90.15083	0.00018	93.58880	93.58886	-6E-05
Fri	1/5/2001	90.19118	90.19101	0.00017	93.55146	93.55162	-0.00016
Sat	1/6/2001	90.21163	90.21112	0.00051	93.53223	93.53265	-0.00042
Sun	1/7/2001	90.22208	90.22179	0.00029	93.52242	93.52317	-0.00075
Mon	1/8/2001	90.14516	90.14288	0.00228	93.51741	93.51688	0.00053
Tue	1/9/2001	90.17995	90.17748	0.00247	93.55019	93.55141	-0.00122
Wed	1/10/2001	90.12680	90.12670	0.00010	86.86744	86.86875	-0.00131
Thu	1/11/2001				85.92797	85.92938	-0.00141
Fri	1/12/2001	67.27759	67.27896	-0.00137	83.43361	83.43401	-0.00040
Fri	1/12/2001	79.27258	79.27032	0.00226			
Sat	1/13/2001	86.65465	86.65105	0.00360	88.50372	88.50614	-0.00242
Sun	1/14/2001	88.07975	88.07861	0.00114	88.97252	88.97538	-0.00286
Mon	1/15/2001	88.67854	88.67837	0.00017	90.38827	90.39020	-0.00193
Tue	1/16/2001	89.07053	89.07072	-0.00019	91.48617	91.48742	-0.00125
Wed	1/17/2001	89.13819	89.13865	-0.00046	85.46148	85.46230	-0.00082
Thu	1/18/2001				84.91795	84.91895	-0.00100
Fri	1/19/2001	66.30531	66.30643	-0.00112	82.78654	82.78692	-0.00038
Fri	1/19/2001	78.78387	78.78181	0.00206			
Sat	1/20/2001	86.37193	86.36850	0.00343	87.99168	87.99393	-0.00225
Sun	1/21/2001	87.86292	87.86184	0.00108	88.60898	88.61167	-0.00269
Mon	1/22/2001	88.60368	88.60346	0.00022	90.15266	90.15442	-0.00176
Tue	1/23/2001	89.01207	89.01221	-0.00014	91.29855	91.29971	-0.00116
Wed	1/24/2001	89.37189	89.37218	-0.00029	92.11501	92.11575	-0.00074
Thu	1/25/2001	89.65321	89.65342	-0.00021	92.64058	92.64088	-0.00030
Fri	1/26/2001	89.85992	89.86003	-0.00011	92.97865	92.97886	-0.00021
Sat	1/27/2001	90.00574	90.00668	-0.00094	93.19607	93.19608	-1E-05
Sun	1/28/2001	90.10716	90.10788	-0.00072	93.33608	93.33611	-3E-05
Mon	1/29/2001	90.09263	90.09263	0.00000	93.42713	93.42673	0.00040
Tue	1/30/2001	90.16294	90.16351	-0.00057	93.51610	93.51631	-0.00021
Wed	1/31/2001	90.11817	90.11805	0.00012	86.85284	86.85269	0.00015
Thu	2/1/2001				85.91833	85.91856	-0.00023
Fri	2/2/2001	67.26837	67.26861	-0.00024	83.42808	83.42805	3E-05
Fri	2/2/2001	79.26945	79.26740	0.00205			
Sat	2/3/2001	86.65311	86.64967	0.00344	88.49880	88.50049	-0.00169
Sun	2/4/2001	88.01655	88.07700	-0.06045	88.96884	88.97103	-0.00219
Mon	2/5/2001	88.67728	88.67695	0.00033	90.38586	90.38730	-0.00144
Tue	2/6/2001	89.06957	89.06958	-1E-05	91.48458	91.48550	-0.00092
Wed	2/7/2001	89.13735	89.13761	-0.00026	85.46034	85.46091	-0.00057
Thu	2/8/2001				84.91714	84.91791	-0.00077
Fri	2/9/2001	66.30453	66.30544	-0.00091	82.78603	82.78620	-0.00017
Sat	2/10/2001	86.37191	86.36834	0.00357	87.99128	87.99338	-0.00210
Sun	2/11/2001	87.86296	87.86185	0.00111	88.60869	88.61131	-0.00262

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Table 21. Comparison of FAST™ and CORE3 PE for last minute of sleep and first minute of work from Schedule 3.

Dependent Meas.		Last Minute of Sleep			First Minute of Work		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Mon	1/1/2001				99.56318	99.56319	-1E-05
Tue	1/2/2001	98.42493	98.42493	0.0000	99.35298	99.35299	-1E-05
Wed	1/3/2001	98.29564	98.29562	2E-05	99.24242	99.24241	1E-05
Thu	1/4/2001	98.22923	98.22928	-5E-05	99.18491	99.18496	-5E-05
Fri	1/5/2001	98.19489	98.19505	-0.00016	99.15526	99.15539	-0.00013
Sat	1/6/2001	98.17717	98.17756	-0.00039			
Sun	1/7/2001	98.16812	98.16881	-0.00069			
Mon	1/8/2001	98.16350	98.16303	0.00047	96.30283	96.30296	-0.00013
Tue	1/9/2001	98.19345	98.19457	-0.00112	96.31800	96.31831	-0.00031
Wed	1/10/2001	91.78504	91.78632	-0.00128	92.00484	92.00649	-0.00165
Thu	1/11/2001	90.84010	90.84148	-0.00138	91.27648	91.27826	-0.00178
Thu	1/11/2001				86.91652	86.91592	0.0006
Fri	1/12/2001	88.38613	88.38653	-0.00040			
Sat	1/13/2001	93.25964	93.26195	-0.00231			
Sun	1/14/2001	93.75527	93.75801	-0.00274			
Mon	1/15/2001	95.13906	95.14092	-0.00186	93.80210	93.80321	-0.00111
Tue	1/16/2001	96.20479	96.20599	-0.00120	94.65530	94.65614	-0.00084
Wed	1/17/2001	90.39235	90.39317	-0.00082	90.51452	90.51545	-0.00093
Thu	1/18/2001	89.83952	89.84050	-0.00098	90.21629	90.21751	-0.00122
Thu	1/18/2001				86.22884	86.22839	0.00045
Fri	1/19/2001	87.74346	87.74382	-0.00036			
Sat	1/20/2001	92.75857	92.76073	-0.00216			
Sun	1/21/2001	93.39901	93.40160	-0.00259			
Mon	1/22/2001	94.90878	94.91048	-0.00170	95.94359	95.94524	-0.00165
Tue	1/23/2001	96.02303	96.02415	-0.00112	97.04151	97.04260	-0.00109
Wed	1/24/2001	96.81345	96.81416	-0.00071	97.81046	97.81114	-0.00068
Thu	1/25/2001	97.32180	97.32209	-0.00029	98.30509	98.30537	-0.00028
Fri	1/26/2001	97.64874	97.64894	-0.00020	98.62393	98.62415	-0.00022
Sat	1/27/2001	97.85906	97.85909	-3E-05			
Sun	1/28/2001	97.99455	97.99458	-3E-05			
Mon	1/29/2001	98.08128	98.08092	0.00036	96.23186	96.23173	0.00013
Tue	1/30/2001	98.16245	98.16264	-0.00019	96.29234	96.29234	0.00000
Wed	1/31/2001	91.77068	91.77052	0.00016	91.98896	91.98882	0.00014
Thu	2/1/2001	90.83057	90.83080	-0.00023	91.26607	91.26646	-0.00039
Thu	2/1/2001				86.91145	86.91078	0.00067
Fri	2/2/2001	88.38064	88.38061	3E-05			
Sat	2/3/2001	93.25484	93.25645	-0.00161			
Sun	2/4/2001	93.75166	93.75377	-0.00211			

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Test Schedule 4

Characteristics:

- 52-day schedule for a train operator ending in a train mishap
- The mishap was the collision of two trains
- No travel in the schedule
- Non standard sleep times resulting from an erratic work schedule

The last and first minute awake measures for Schedule 4 are shown in Table 22 with the last minute of sleep and the first minute of work measures shown in Table 23. The data points of these tables are representative of all points generated by both applications for Scenario 4. The differences between the data values for the two programs appear to be insignificant. Further, the data values from this Schedule 4 are identical to those of Schedule 4 from the previous test, CORE3.

Table 22. Comparison of FAST™ and CORE3 PE for last and first minute awake from Schedule 4.

Dependent Meas.		Last Minute Awake			First Minute Awake		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Fri	1/2/2004	73.69163	73.69163	0.00000			
Fri	1/2/2004	76.30443	76.30320	0.00123	77.51918	77.51919	-0.00001
Sat	1/3/2004	87.50912	87.50693	0.00219	85.61922	85.62067	-0.00145
Sun	1/4/2004	88.30235	88.30170	0.00065	86.68018	86.68214	-0.00196
Mon	1/5/2004	88.60458	88.60449	0.00009	88.83073	88.83208	-0.00135
Tue	1/6/2004	83.75427	83.75454	-0.00027	83.60858	83.60944	-0.00086
Wed	1/7/2004	85.16464	85.16457	0.00007	89.47795	89.47879	-0.00084
Thu	1/8/2004	87.24010	87.24013	-0.00003	91.78574	91.78629	-0.00055
Fri	1/9/2004	83.75146	83.75153	-0.00007	85.62943	85.62977	-0.00034
Sat	1/10/2004	80.30466	80.30477	-0.00011	83.71000	83.71030	-0.00030
Sun	1/11/2004	83.37723	83.37733	-0.00010	90.68758	90.68779	-0.00021
Mon	1/12/2004	86.35214	86.35220	-0.00006	92.54987	92.54999	-0.00012
Tue	1/13/2004	73.42200	73.42210	-0.00010	79.20998	79.21006	-0.00008
Wed	1/14/2004	79.81280	79.81299	-0.00019	72.55933	72.55943	-0.00010
Wed	1/14/2004	86.74080	86.74143	-0.00063	78.31586	78.31600	-0.00014
Wed	1/14/2004	79.66622	79.66511	0.00111	86.04544	86.04500	0.00044
Thu	1/15/2004	71.31468	71.31557	-0.00089	73.17825	73.17737	0.00088
Thu	1/15/2004	87.07670	87.07771	-0.00101	78.99375	78.99393	-0.00018
Thu	1/15/2004				85.50927	85.50949	-0.00022
Fri	1/16/2004	58.83827	58.83870	-0.00043	86.44967	86.44942	0.00025
Sat	1/17/2004	62.39096	62.39148	-0.00052	87.38006	87.37908	0.00098
Sat	1/17/2004	84.93193	84.92500	0.00693			
Sun	1/18/2004	89.38913	89.38338	0.00575	87.95602	87.96042	-0.00440
Mon	1/19/2004	89.35497	89.35323	0.00174	87.83222	87.83738	-0.00516
Tue	1/20/2004	89.22559	89.22535	0.00024	89.48136	89.48495	-0.00359
Wed	1/21/2004	89.25824	89.25859	-0.00035	90.86380	90.86623	-0.00243
Thu	1/22/2004	89.44929	89.44976	-0.00047	91.83475	91.83633	-0.00158

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Dependent Meas.		Last Minute Awake			First Minute Awake		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Fri	1/23/2004	89.66058	89.66112	-0.00054	92.46056	92.46159	-0.00103
Sat	1/24/2004	89.84263	89.84296	-0.00033	92.86306	92.86371	-0.00065
Sun	1/25/2004	89.99337	89.99379	-0.00042	83.05505	83.05554	-0.00049
Mon	1/26/2004				84.33176	84.33257	-0.00081
Tue	1/27/2004	62.57320	62.57474	-0.00154	88.63964	88.63927	0.00037
Tue	1/27/2004	83.24174	83.23598	0.00576			
Wed	1/28/2004				90.37003	90.37368	-0.00365
Thu	1/29/2004	65.29173	65.29198	-0.00025	90.88000	90.87880	0.00120
Fri	1/30/2004				87.07378	87.07176	0.00202
Sat	1/31/2004	76.38966	76.37315	0.01651	87.50317	87.50909	-0.00592
Sat	1/31/2004	92.08941	92.08238	0.00703			
Sun	2/1/2004	91.15131	91.15075	0.00056	85.03180	85.03970	-0.00790
Mon	2/2/2004				86.17938	86.18745	-0.00807
Tue	2/3/2004	82.73487	82.73067	0.00420	91.61659	91.62271	-0.00612
Tue	2/3/2004	92.05651	92.05537	0.00114			
Wed	2/4/2004	91.46796	91.46856	-0.00060	89.76778	89.77271	-0.00493
Thu	2/5/2004	90.44686	90.44778	-0.00092	90.36954	90.37286	-0.00332
Fri	2/6/2004				91.41220	91.41439	-0.00219
Sat	2/7/2004	79.54833	79.54929	-0.00096	92.44851	92.44986	-0.00135
Sat	2/7/2004	90.81990	90.82060	-0.00070			
Sun	2/8/2004	91.07545	91.07577	-0.00032	91.28060	91.28176	-0.00116
Mon	2/9/2004	90.47749	90.47776	-0.00027	91.60709	91.60783	-0.00074
Tue	2/10/2004	90.18804	90.18833	-0.00029	92.23826	92.23881	-0.00055
Wed	2/11/2004				92.70465	92.70497	-0.00032
Thu	2/12/2004	68.92368	68.92396	-0.00028	92.55322	92.55338	-0.00016
Thu	2/12/2004	91.03803	91.03689	0.00114			
Fri	2/13/2004	93.11156	93.11057	0.00099	90.54367	90.54552	-0.00185
Sat	2/14/2004	91.37703	91.37682	0.00021	89.33224	89.33373	-0.00149
Sun	2/15/2004	90.46864	90.46869	-0.00005	90.49357	90.49459	-0.00102
Mon	2/16/2004	77.00135	77.00210	-0.00075	82.79808	82.79813	-0.00005
Mon	2/16/2004	79.67215	79.67159	0.00056	81.49096	81.49145	-0.00049
Tue	2/17/2004	78.53182	78.53189	-0.00007	77.07245	77.07319	-0.00074
Wed	2/18/2004				85.08425	85.08565	-0.00140
Thu	2/19/2004	69.61806	69.61920	-0.00114			
Fri	2/20/2004	78.34732	78.35152	-0.00420	71.68479	71.68562	-0.00083
Fri	2/20/2004				82.61905	82.61832	0.00073

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Table 23. Comparison of FAST™ and CORE3 PE for last minute of sleep and first minute of work from Schedule 4.

Dependent Meas.		Last Minute of Sleep			First Minute of Work		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Thu	1/1/2004				97.86626	97.86626	0.00000
Fri	1/2/2004	82.57455	82.57455	0.00000			
Sat	1/3/2004	90.47451	90.47592	-0.00141			
Sun	1/4/2004	91.52749	91.52938	-0.00189			
Mon	1/5/2004	93.62874	93.63004	-0.00130			
Tue	1/6/2004	88.56032	88.56116	-0.00084	88.41396	88.41498	-0.00102
Wed	1/7/2004	94.23886	94.23967	-0.00081			
Thu	1/8/2004	96.45840	96.45892	-0.00052	97.76994	97.77034	-0.00040
Fri	1/9/2004	90.54858	90.54891	-0.00033	90.88580	90.88619	-0.00039
Sat	1/10/2004	88.64700	88.64730	-0.00030	89.01942	89.01976	-0.00034
Sun	1/11/2004	95.38196	95.38216	-0.00020	95.35115	95.35130	-0.00015
Mon	1/12/2004	97.16863	97.16874	-0.00011			
Tue	1/13/2004	84.27356	84.27364	-0.00008	80.73091	80.73101	-0.00010
Wed	1/14/2004	77.62017	77.62026	-0.00009	75.54720	75.54750	-0.00030
Wed	1/14/2004	83.33318	83.33333	-0.00015			
Wed	1/14/2004	90.96787	90.96745	0.00042			
Thu	1/15/2004	78.28695	78.28607	0.00088	72.65913	72.65846	0.00067
Thu	1/15/2004	83.97604	83.97621	-0.00017	88.77426	88.77377	0.00049
Thu	1/15/2004	90.38652	90.38675	-0.00023			
Fri	1/16/2004	91.24361	91.24335	0.00026	90.12574	90.12624	-0.00050
Sat	1/17/2004	92.16851	92.16757	0.00094			
Sun	1/18/2004	92.74571	92.74993	-0.00422			
Mon	1/19/2004	92.66276	92.66776	-0.00500			
Tue	1/20/2004	94.27023	94.27372	-0.00349			
Wed	1/21/2004	95.60949	95.61182	-0.00233	96.88406	96.88627	-0.00221
Thu	1/22/2004	96.54668	96.54821	-0.00153	98.27170	98.27287	-0.00117
Fri	1/23/2004	97.15013	97.15114	-0.00101	97.40405	97.40480	-0.00075
Sat	1/24/2004	97.53825	97.53889	-0.00064	97.95610	97.95659	-0.00049
Sun	1/25/2004	88.05299	88.05348	-0.00049	86.67231	86.67281	-0.00050
Mon	1/26/2004	89.26115	89.26195	-0.00080	91.67228	91.67394	-0.00166
Tue	1/27/2004	93.43594	93.43560	0.00034			
Wed	1/28/2004	95.07685	95.08029	-0.00344	96.23190	96.23480	-0.00290
Thu	1/29/2004	95.58203	95.58092	0.00111	92.93190	92.93314	-0.00124
Fri	1/30/2004	91.92841	91.92648	0.00193	91.75258	91.75631	-0.00373
Sat	1/31/2004	92.30656	92.31224	-0.00568			
Sun	2/1/2004	89.94059	89.94830	-0.00771			
Mon	2/2/2004	91.06175	91.06964	-0.00789	91.82639	91.83068	-0.00429
Tue	2/3/2004	96.27854	96.28436	-0.00582	94.52997	94.53284	-0.00287
Wed	2/4/2004	94.56900	94.57378	-0.00478	94.18501	94.18792	-0.00291
Thu	2/5/2004	95.15182	95.15505	-0.00323	94.45319	94.45546	-0.00227
Fri	2/6/2004	96.15227	96.15439	-0.00212	94.94123	94.94286	-0.00163
Sat	2/7/2004	97.11887	97.12018	-0.00131			
Sun	2/8/2004	96.03208	96.03321	-0.00113			
Mon	2/9/2004	96.34706	96.34779	-0.00073			
Tue	2/10/2004	96.94846	96.94901	-0.00055			

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Dependent Meas.		Last Minute of Sleep			First Minute of Work		
		Performance Effectiveness			Performance Effectiveness		
Day	Date	Core Software	FAST™	Difference	Core Software	FAST™	Difference
Wed	2/11/2004	97.39272	97.39304	-0.00032	96.34255	96.34284	-0.00029
Thu	2/12/2004	97.22291	97.22307	-0.00016			
Fri	2/13/2004	95.31711	95.31887	-0.00176			
Sat	2/14/2004	94.15794	94.15939	-0.00145			
Sun	2/15/2004	95.27277	95.27378	-0.00101			
Mon	2/16/2004	87.88034	87.88039	-0.00005	81.96500	81.96511	-0.00011
Mon	2/16/2004	86.49751	86.49799	-0.00048			
Tue	2/17/2004	82.08887	82.08961	-0.00074	80.92321	80.92426	-0.00105
Wed	2/18/2004	89.93004	89.93140	-0.00136			
Thu	2/19/2004				75.37611	75.37297	0.00314
Fri	2/20/2004	76.73950	76.74032	-0.00082	74.16930	74.17168	-0.00238
Fri	2/20/2004	87.56767	87.56699	0.00068			
Sat	2/21/2004				73.57406	73.57032	0.00374

DISCUSSION

What is obvious from the graphs and tables of data from FAST™ and its web-based instantiations is that the initial web-based version, CORE1, was not a good representation, but that the revised versions, CORE2 and CORE3, generated nearly identical performance effectiveness values compared to FAST™. The four test scenarios were selected to assess the important features of the model in each of the two applications: transitions from sleep to wakefulness, sleep inertia, transmeridian travel, recovery from restricted sleep, and very long schedules. The second, web-based version, CORE2, corrected the problems of CORE1 and provided output nearly identical to Version 1.6 of FAST™ in every way. The pharmaceutical fatigue countermeasure algorithms, added to the core software in CORE3, apparently did not affect the predictions when identical scenarios were compared. The small discrepancies found throughout the data can probably be accounted for by rounding differences since the two applications are written in different programming languages.

The validated, web-based version of the model, represented by CORE2, was used as the basis for adding the new pharmaceutical fatigue countermeasures algorithm. At the same time, we added a preconditioning module to properly set the model's parameters for starting a specific schedule. A small set of questions concerning the sleep time prior to starting the schedule have eliminated the need to precondition the model with three days of data prior to the schedule days of interest. The new preconditioning method fills the reservoir with the appropriate amount of sleep debt (if any), and sets the circadian rhythm to the proper acrophase before computing the output from the schedule of interest. This approach preconditions the parameters of the model so that the schedule of interest is not affected by incorrect starting values for sleep and acrophase at the start of the schedule. The FAST™ approach provides only three days of sleep to stabilize the sleep reservoir level and circadian rhythm, which may not be enough before starting a new schedule.

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This could potentially contaminate the projections for the new schedule with unrealistic beginning model parameters. The consequence might be unnecessary shifting and depleting of the reservoir that can lower performance effectiveness below what should be projected for a schedule of interest. The new preconditioning method attempts to obviate those circumstances.

The CORE3 software is now the core software module for F-PAS. It has three task centered interfaces for mishap investigation, shift work scheduling, and mission planning. Each interface is described along with usability testing in separate publications (Eddy, Miller, Welch, Smith, & Moise, 2009, *Mishap Investigator Interface*; Miller, Eddy, Smith, & Moise, 2009, *Shiftwork Scheduler Interface*; Eddy, Moise, Miller, & Smith, 2009, *Mission Scheduler Interface*). The final report for the project is contained in Eddy, Miller, & Moise (2008).

An additional new feature will be a transmeridian algorithm for Autosleep. This will give schedulers a way to automatically load the model with the sleep expected for a particular schedule that crosses time zones. If schedulers know what time and duration a crew will sleep for a specific schedule, those times and durations can always be used instead of sleep generated by Autosleep, however.

In the future, the new concepts will be tested against FAST™ in an appropriate way. Since the new methods have no specific analogs in FAST™, only a limited comparison will be possible. For example, we can compare the new preconditioning module with using the 3-day, preconditioning approach of FAST™. We can compare the transmeridian Autosleep algorithm with the more limited FAST™ Autosleep for inserting sleep into a schedule when it does not include time zone crossings. While the pharmaceutical fatigue countermeasure algorithms have been validated by comparing the output of CORE3 against the protocol schedule and results of Wesensten, Killgore, & Balkin (2005), it is essential to ensure that the output graphs and data tables from F-PAS are also valid. It was our hope to include these results with this report, but the deadline for the delivery of this report arrived before the software was ready to test. Therefore, that information will have to be reported elsewhere.

CONCLUSIONS

The new web-based version of FAST™, CORE3, has been verified against FAST™ and is ready for testing the new features against data from laboratory studies. Testing has shown that performance effectiveness under conditions of sleep-wakefulness transitions, sleep inertia, transmeridian travel, recovery from restricted sleep, and very long schedules is nearly identical for the two applications.

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REFERENCES

Chaiken SR (2005). *A Verification and Analysis of the USAF/DOD Fatigue Model and Fatigue Management*. (AFRL Technical Report No. AFRL-HE-BR-TR-2005-0162). Brooks City-Base, TX: Human Effectiveness Directorate, Biosciences and Protection Division, Fatigue Countermeasures Branch.

Eddy DR, & Hursh SR (2001). *Fatigue Avoidance Scheduling Tool (FAST™)*. (AFRL Technical Report No. AFRL-HE-BR-TR-2001-0140). Brooks AFB, TX: Human Effectiveness Directorate Biodynamics and Protection Division, Flight Motion Effects Branch.

Eddy DR, & Hursh SR (2006a). *Fatigue Avoidance Scheduling Tool (FAST™) Phase II SBIR Final Report, Part 1*. (AFRL Technical Report No. AFRL-HE-BR-TR-2006-0015). Brooks City-Base, TX: Human Effectiveness Directorate, Biosciences and Protection Division, Fatigue Countermeasures Branch.

Eddy DR, & Hursh SR (2006b). *Fatigue Avoidance Scheduling Tool (FAST™) Phase II SBIR Final Report, Part 2*. (AFRL Technical Report No. AFRL-HE-BR-TR-2006-0040). Brooks City-Base, TX: Human Effectiveness Directorate, Biosciences and Protection Division, Fatigue Countermeasures Branch.

Eddy DR, Miller JC, & Moise SL (2008). 24/7 Operational Effectiveness Toolset: Final Report. Technical Report, AFRL-RH-BR-TR-2008-0066, Contract FA8650-06-C-6606, Air Force Research Laboratory, Brooks City-Base, TX.

Eddy DR, Miller JC, Welch C, Smith R, & Moise SL (2009). *24/7 Operational Effectiveness Toolset: Mishap Investigator Interface*. Technical Report, AFRL-RH-BR-TR-2009-0031, Contract FA8650-06-C-6606). Brooks City-Base, TX: Human Effectiveness Directorate, Biosciences and Protection Division, Biobehavioral Performance Branch.

Eddy DR, Moise SL, Miller JC, & Smith R (2009). *24/7 Operational Effectiveness Toolset: Mission Scheduler Interface*. AFRL Technical Report, AFRL-RH-BR-TR-2009-0035, Contract FA8650-06-C-6606). Brooks City-Base, TX: Human Effectiveness Directorate, Biosciences and Protection Division, Biobehavioral Performance Branch.

Hursh SR, Raslear TG, Kaye AS, & Fanzone JF (2006). *Validation and Calibration of a Fatigue Assessment Tool for Railroad Work Schedules, Summary Report*. (FRA Agency Report No. DOT/FRA/ORD-06/21). Washington, DC: U.S. Department of Transportation, Federal Railroad Administration, Office of Research and Development.

Hursh SR, Redmond DP, Johnson ML, Thorne DR, Belenky G, Balkin TJ, Storm WF, Miller JC, & Eddy DR (2004). Fatigue models for applied research in warfighting. *Aviat Space Environ Med*, *75*(3, Suppl.): A44–53.

Miller JC, Eddy DR, Smith R, & Moise SL (2009). *24/7 Operational Effectiveness Toolset: Shiftwork Scheduler Interface*. Technical Report, AFRL-RH-BR-TR-2009-0032, Contract FA8650-06-C-6606). Brooks City-Base, TX: Human Effectiveness Directorate, Biosciences and Protection Division, Biobehavioral Performance Branch.

Wesensten NJ, Killgore WS, & Balkin TJ (2005). Performance and alertness effects of caffeine, dextroamphetamine, and modafinil during sleep deprivation. *J. Sleep Res. 14*, 255–266.

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